Program Devel. Office

WATER RESOURCE DEVELOPMENT PROJECT

CHANNEL REHABILITATION PROJECT
LOCAL PROTECTION

NORTH NASHUA RIVER BASIN

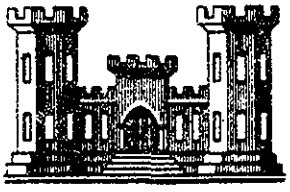
FITCHBURG, MASSACHUSETTS

GENERAL

DESIGN MEMORANDUM NO. 1

COMBINED

PHASE I-PLAN FORMULATION
PHASE II-GENERAL DESIGN



DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

DECEMBER 1977

DISPOSITION FORM

For use of this form, see AR 340-15, the proponent agency is TAGCEN.

REFERENCE OR OFFICE SYMBOL	SUBJECT
NEDED-E	North Nashua River, Fitchburg, Mass.

TO: Chief, Real Estate Div
Chief, Planning Div
Chief, Operations Div
Chief, Construction Div
Chief, Design Branch
Chief, F & M Branch
Prog Dev Ofc. ✓

FROM: Chief, Engrg Division

DATE: 6 March 1978

CMT 1: Mr. Levin/dek/512

1. Ref: Memo OCE, 24 Feb 78 - 1st Ind (copy attached).

2. Approval of GDM for referenced project is noted with two minor comments relating to assurances and design considerations.

Fryar

FRYAR

Incl
as

CF: Mr. Levin
Eng Div Files

DAEN-CWE-BB (NEDED-E, 9 Dec 77) 1st Ind
SUBJECT: Channel Rehabilitation Project, Local Protection, North Nashua River Basin, Fitchburg, Massachusetts; Combined General Memorandum No. 1, Phase I - Plan Formulation and Phase II - General Design

DA, Office of the Chief of Engineers, Washington, D.C. 20314 24 February 1978

TO: Division Engineer, New England, ATTN: NEDED-E

1. The subject design memorandum is approved, subject to the comments in the following paragraphs.

2. The local cooporation requirements on page 6 should quote verbatim the requirements as stated in the Senate Document 113, 89th Congress, 2nd Session, North Nashua River and tributaries, Merrimack River Basin, Massachusetts, 6 October 1966 (see ER 1110-2-1150, Appendix A, paragraph 2a). The local cooperation requirements on page 63 should be modified by ~~the~~ adding to the hold and save clause (paragraph b) "except damages due to the fault or negligence of the United States or its contractors," as required by Public Law 93-251. The formal local cooperation agreement wording of the local cooperation requirements must be in strict conformance with the project document wording as modified by Public Law 93-251.

3. Plates 1, 2, and 4. Plans and specifications should provide for positive drain measures where cut stone or riprap is to be grouted.

FOR THE CHIEF OF ENGINEERS:

R. L. Hopson

1 Incl
wd

HOMER B. WILLIS
Chief, Engineering Division
Directorate of Civil Works

NEDED-E 9 December 1977

SUBJECT: Channel Rehabilitation Project, Local Protection, North Nashua River Basin, Fitchburg, Massachusetts; Combined General Memorandum No. 1, Phase I - Plan Formulation and Phase II - General Design.

HQDA(DAEN-CWE-BB)
WASH D C 20314

1. References:

a. NED letter dated 9 March 1976 to HQDA(DAEN-CWP-E), subject: "Waiver of Phase I GDM Requirements for North Nashua Restoration Project" and 1st Indorsement thereto dated 5 April 1976 which approved recomendation that NED prepare a General Design Memorandum (GDM) which combines Phases I and II components.

b. Telephone discussion between your Mr. Robert Elliston, OCE and Mr. James Callahan, this Division, on 18 August 1977 wherein Mr. Callahan advised Mr. Elliston of the project GDM status and requested that because no controversial items of design were in the project, that a representative of this Division meet with OCE personnel during the week of 26 September 1977 to discuss the project design. This meeting fulfilled Milestone No. 8.

c. Design Conference (Milestone No. 8) conducted in Office Chief of Engineers on 4 October 1977.

2. In accordance with ER 1110-2-1150 there is submitted herewith for your review and comments a combined General Design Memorandum (GDM) No. 1, Phase I - Plan Formulation and Phase II - General Design for the Channel Rehabilitation Project, Local Protection, North Nashua River Basin, Fitchburg, Massachusetts.

3. This memorandum reflects some minor type departures in the scope of work from that authorized in the 1965 Survey Scope report. A description of the departures and the reasons for change are included in the text of the GDM.

4. In review of the GDM the following is noted in respect to the relationship of the Channel Rehabilitation Project with the proposed upstream Reservoirs and Dams:

The channel is only one component of the overall Water Resources Development Plan for the North Nashua River Basin. The other components consist of upstream reservoirs and dams (Whitmanville and Phillips Lakes) and other channel improvement work on Baker and Monoosnoc Brooks.

Substantial efforts and public involvement have been carried out over the past years to construct the overall project, however, reaction to construct the reservoirs and dams have been extremely controversial and no public decision or agreement has been reached to date.

The channel project has not been such a controversial issue and local and state interests look favorably upon the project. Further, the City Council of Fitchburg by Resolution dated 15 December 1976 in essence went on record as favoring the channel restoration project and that it be first completed and reviewed prior to approval of any subsequent construction of dams, and that funds be made available for a complete restoration.

5. An Environmental Assessment has been prepared for the project in lieu of an Environmental Impact Statement (EIS) and is attached to the GDM as an Appendix. The Environmental Assessment is in process of being distributed to interested agencies for information and comment. The Environmental Assessment supersedes the draft EIS which was submitted to Council on Environmental Quality (CEQ) on 14 April 1971.

6. Section A E of the Memorandum presents the Statement of Findings prepared in accordance with ED 1105-2-501 dated 17 April 1972. Also, included as an attachment to the GDM is a Section 404 Evaluation Report required under PL 92-500,"Federal Water Pollution Control Act Amendments of 1972."

7. On 8 August 1977 a letter was forwarded to the City of Fitchburg advising them of the status of the project as well as a map and description of the proposed work items involved in the channel. The city was requested to advise this Division if it agrees to our continuance of further design, preparation of contract documents, construction of the project, and items of cooperation. On 22 August 1977 the city responded by letter for NED to continue with design of the project.

8. The present schedule for the project is:

NEDED-E
SUBJECT: Channel Rehabilitation, etc.

ITEM	Scheduled Date
-Submit preliminary draft GDM(Phases I & II)	31 Aug 77
-Conduct Design Conference with OCE	4 Oct 77*
-Incorporate OCE comments and submit GDM (Phases I & II)	Nov 77**
-Receive OCE comments on GDM, incorporate same and proceed with final plans and specifications	Jan 78
-Incorporate comments	Feb 78
-Complete plans and specifications	31 Mar 78
-Obtain assurances	31 Mar 78
-Advertise for bids	Sep 78
-Open bids and award	Oct 78
-Complete construction	Jun 80

*Milestone 8

**Milestone 9

9. It is recommended that the project plan providing flood protection and channel rehabilitation in the city of Fitchburg be approved as the basis for preparation of Contract Plans and Specifications.

FOR THE DIVISION ENGINEER:

Joe B. Fryar

Incl (cy)
as

JOE B. FRYAR
Chief, Engineering Division

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NORTH NASHUA RIVER
CHANNEL REHABILITATION PROJECT
FITCHBURG, MASSACHUSETTS

PHASES I AND II - COMBINED GENERAL DESIGN MEMORANDUM

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LIST OF PLATES

ATTACHMENT A

LETTERS OF COMMENT AND CONCURRENCE

Att. No.	Date	Letter From
A-1	13 Sept 76	Governor, Comm. of Mass.
A-2	16 Dec 76	Board of City Council, Fitchburg, Mass.
A-3	22 Aug 77	Mayor, City of Fitchburg, Mass.

ATTACHMENT B

B — Project Cost and Estimate

ATTACHMENT C

C — Section 404 Evaluation Report

ATTACHMENT D

D — Structural Computations

ATTACHMENT E

E — Stage Damage Curves

APPENDICES

App. No.	Title
I	HYDROLOGIC ANALYSIS
II	ENVIRONMENTAL ASSESSMENT
III	SOCIAL AND ECONOMICS EFFECTS ASSESSMENT

SYLLABUS

Design Memorandum No. 1 is for the authorized Channel Rehabilitation Project, Local Flood Protection, located in North Nashua River, Fitchburg, Massachusetts. It is a combined design memorandum in that it includes Phase I - Plan Formulation and Phase II - General Design data.

As a result of the floods of March 1936, Congress immediately authorized a flood protection project in the area and the Corps of Engineers completed construction of the works in 1937. Subsequent floods damaged the facilities above normal maintenance activities and the current project is a rehabilitation and restoration of the 1936 project.

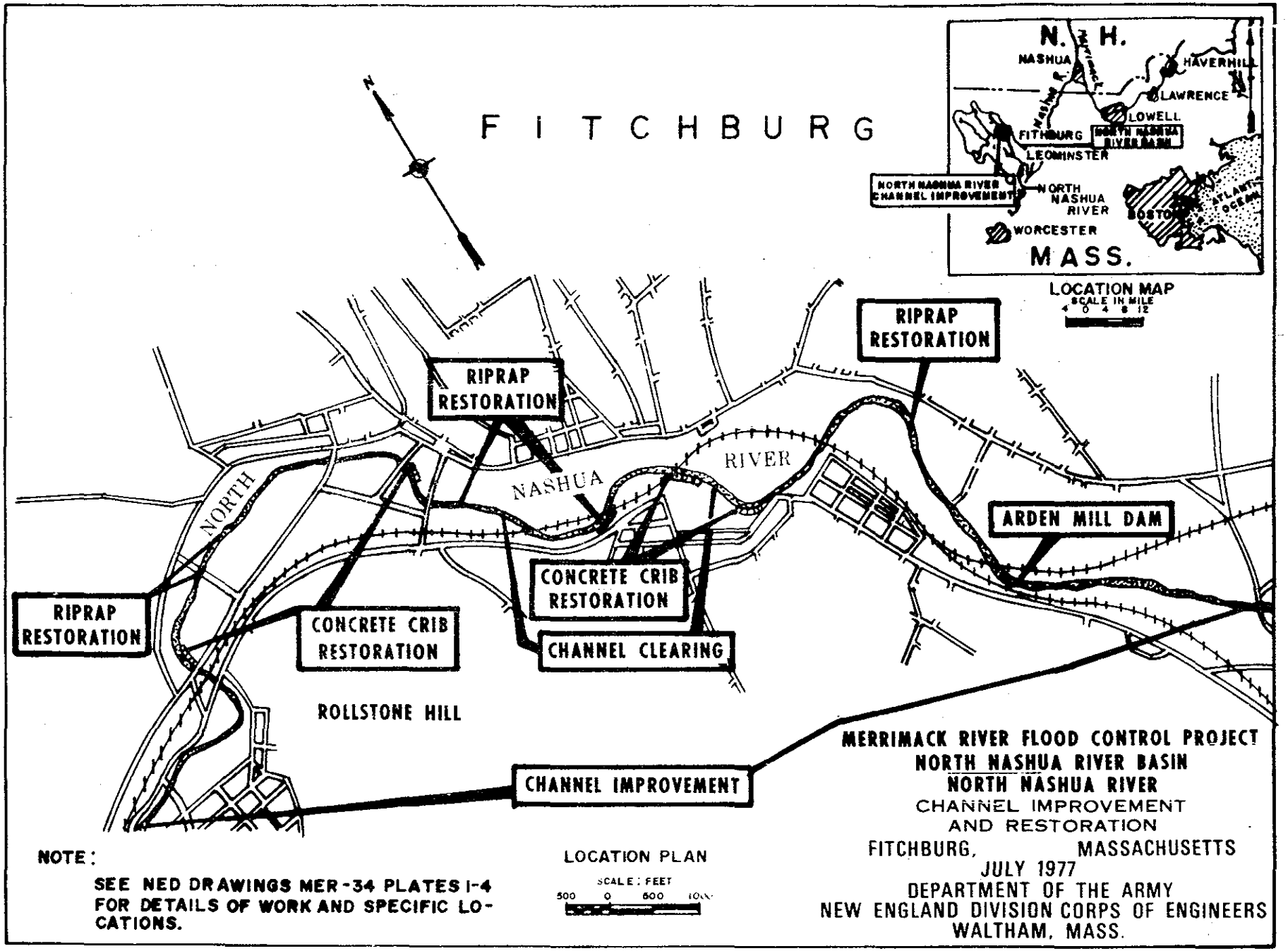
In January 1965 the New England Division completed a Survey Scope Report on a Water Resource Development Plan for the North Nashua River Basin which is part of the overall Merrimack River Basin. In this report sites upstream of the channel project site were considered for flood protection, water supply and recreational opportunities, as well as the reporting on the channel rehabilitation work in the city of Fitchburg. The overall water resource development plan was authorized by the Congress in 1966 and various degrees of planning and engineering efforts for all major components of the plan have been performed. To date no decision by the public has been made to construct the upstream dams and reservoirs, however, the local and State officials look favorably upon the channel improvement component.

The project extends over an approximate 4.4 mile reach of the stream and consists of about 23 individual work locations involving reconstruction of flood walls, bank stabilization, riprap construction and removal of shoal areas. The estimated construction contract cost of the work is $1,650,000 and when engineering, design, supervision and administration costs are included the Total Estimated First Cost of the project is $2,100,000. The estimated construction period is eighteen months.

An Environmental Assessment has been prepared for the project in lieu of an Environmental Impact Statement as the work is of a rehabilitation nature and is considered a minor action type project. The Design Memorandum addresses environmental, economic and social considerations and impacts and the project is part of both the National Economics Development (NED) and the Environmental Quality (EQ) plan for the overall North Nashua River Basin Flood Protection Plan.

The project first costs will be borne by the Federal Government, however, the annual operational maintenance costs will be the responsibility of the city of Fitchburg. The estimated annual benefits derived from flood protection afforded by the project is $410,000 and the estimated annual cost is $150,500 which results in a Benefit-Cost Ratio (BCR) of 2.7 to 1 based on an interest rate of 6-5/8%.

The project is considered highly beneficial to the local interests and the proposed schedule is to advertise a construction contract in the Fall of 1978 and to complete the work by mid 1980.


F I T C H B U R G
N.
H.
NASHUA
HAVERHILL
LAWRENCE
LOWELL
FITHBURG
LEOMINSTER
NORTH NASHUA RIVER CHANNEL IMPROVEMENT
NORTH NASHUA RIVER
BOSTON
ATLANTIC OCEAN
WORCESTER
MASS.
LOCATION MAP
SCALE IN MILE
4 0 4 8 12
RIPRAP RESTORATION
RIPRAP RESTORATION
RIPRAP RESTORATION
NASHUA
RIVER
NORTH
ARDEN MILL DAM
CONCRETE CRIB RESTORATION
CONCRETE CRIB RESTORATION
CHANNEL CLEARING
ROLLSTONE HILL
CHANNEL IMPROVEMENT
NOTE:
SEE NED DRAWINGS MER-34 PLATES 1-4 FOR DETAILS OF WORK AND SPECIFIC LOCATIONS.
LOCATION PLAN
SCALE: FEET
500 0 500 1000
MERRIMACK RIVER FLOOD CONTROL PROJECT
NORTH NASHUA RIVER BASIN
NORTH NASHUA RIVER
CHANNEL IMPROVEMENT
AND RESTORATION
FITCHBURG, MASSACHUSETTS
JULY 1977
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION CORPS OF ENGINEERS
WALTHAM, MASS.

AF ENVIRONMENTAL ASSESSMENT

An Environmental Assessment, Appendix II, has been prepared for the project in lieu of an Environmental Impact Statement. The project is considered a minor action type of project primarily because of its rehabilitation and restoration aspects. The reasons for using an assessment are provided in the Appendix.

Other attached documents relating to environmental and social-economic issues contained in this Design Memorandum are:

Appendix III - Social and Economic Effects Assessment

Attachment C - Section 404 Evaluation Report

NORTH NASHUA RIVER FLOWING THROUGH FITCHBURG'S DOWNTOWN BUSINESS SECTION.
PUTNAM STREET IS IN CENTER.

WATER RESOURCES DEVELOPMENT PROJECT

A. PERTINENT DATA FOR PROPOSED NORTH NASHUA RIVER CHANNEL REHABILITATION, LOCAL PROTECTION, NORTH NASHUA RIVER BASIN, FITCHBURG, MASSACHUSETTS

The following is some of the pertinent data for the project:

Item	Data
PURPOSE	Overbank flood control of North Nashua River
LOCATION	
State	Massachusetts
County	Worcester
City	Fitchburg
River	North Nashua River
River Basin	North Nashua
TYPE OF IMPROVEMENT	Rehabilitation of existing project, Repairs to walls and cribs, rehabilitation of slope protection, channel excavation, removal of channel obstructions and depositions. (23 locations)

NORTH NASHUA RIVER DRAINAGE AREAS

Whitman River	27.5 Square Miles
Flagg Brook	12.0 Square Miles
Phillips Brook	16.0 Square Miles
Local	8.0 Square Miles

Above Arden Mill Dam

RECORD OF MAJOR FLOODS

Year	Month	*Peak Discharge, cfs
1936	March	9,400
1938	September	8,900
1955	October	7,800

*The peak discharge was computed at Arden Mill Dam

HYDROLOGY

Maximum flood of record	9,400 cfs
Project design flood	9,000 cfs
Drainage area	63.5 Square Miles

LENGTH (Project Work Site)	4.4 miles
BOTTOM WIDTH	Controlled by existing project
TYPE OF PROPERTIES PROTECTED	Industrial, commercial, residential and public
LANDS AND DAMAGES	None
RELOCATIONS	None
EASEMENTS REQUIRED	Only temporary easements for construction

PRINCIPAL QUANTITIES

Excavation*	13,700 cubic yards*
Rock protection	6,300 cubic yards
Remove existing riprap	1,100 cubic yards
Concrete walls and caps	2,400 cubic yards
Filter stone	1,800 cubic yards
Gabions	300 cubic yards
Gravel bedding	2,100 cubic yards
Remove existing cribs	1,600 cubic yards

*Excluding shoaling excavation

ESTIMATED PROJECT COST

(1977 Price Levels)

Total first cost	$2,100,000

COST APPORTIONMENT

Federal	$2,100,000
Non-Federal	None

ECONOMIC ANALYSIS

	3-1/4%	6-5/8%
Annual Benefits	$428,000	$410,000
Annual Costs	91,000	150,500
Benefit Cost Ratio	4.7 to 1.0	2.7 to 1.0

CONSTRUCTION PERIOD — 18 Months

PROJECT DOCUMENT — Senate Document No. 113, 89th Congress, 2nd Session (PL 89-789)

PROJECT AUTHORIZATION — Flood Control Act of 1966

B. INTRODUCTION

1. General - The North Nashua River Basin has historically been subject to flooding and surveys of flood damages were made after the 1938 and 1955 floods. Detailed damage surveys were accomplished in 1962 and a Survey Scope Report was prepared in January 1965. One of the principal items proposed to reduce the flooding losses was the construction of various local protection improvements in the channel of the river mainstem, identified as the North Nashua River Channel Rehabilitation Project.

Extensive improvements were made in the river channel through Fitchburg following the disastrous flood of March 1936. Other major floods occurred in September 1938, June 1944 and October 1955. Improvements consisted of removal of dams, channel straightening and enlarging, plus the construction of retaining walls and revetments. The improved channel was designed to safely convey a flow equal in magnitude to the March 1936 flood. The improvements have since deteriorated and require rehabilitation in order to safely convey the original design flow. Such rehabilitation is a necessity to insure the integrity of any comprehensive flood control plan for the area and was therefore made an integral part of the flood control plan as set forth in 1965 report, entitled: "Water Resources Development Plan, North Nashua River Basin."

During the Survey Scope Study stage, various methods of providing flood protection within the North Nashua River Basin were formulated and evaluated. The most economically advantageous plan to reduce flooding in Fitchburg consisted of restoring the deteriorated channel to its 1937 condition (channel capacity - 9,000 cfs) and construction of three upstream reservoirs, namely: Phillips, Nookagee and Whitmanville. This plan subsequently referred to as the National Economic Development, "NED" plan, was recommended in the 1965 Survey Report (subsequently published as Senate Document No. 113, 89th Congress, 2nd Session) and authorized under Title II, Section 203 of the 1966 Flood Control Act.

Since that time, local opinions and desires have necessitated a need for a change in the authorized plan. The location of the flood control reservoirs upstream of Fitchburg have been altered but the revised plan still requires a restored channel through the center of Fitchburg. The channel rehabilitation project is also part of the Environmental Quality (EQ) plan which includes the channel work and construction of two upstream reservoirs and dams at Phillips and Whitmanville.

In summary, the channel improvements are a necessary part of either the NED or EQ plan, the latter of which is the more preferred plan from the public point of view.

It is noted that this memorandum may refer to but does not apply to other proposed projects in the North Nashua River Basin such as the proposed Phillips, Monoosnoc, Nookage or Whitmanville Dams and Reservoirs, or the channel improvements in Baker and Monoosnoc Brooks. These other projects are still authorized and are in various stages of planning and design. The projects have been presented to the public through an open planning process. However, over the past few years considerable opposition to the dams and reservoirs has emerged and approval and decisions to construct them has not been realized. Presently, concurrence to construct the dams and reservoirs in the immediate future does not appear too promising.

In contrast, latest indications from the public based on a Public Meeting conducted in October 1976 by the New England Division, are that the North Nashua River channel rehabilitation project is acceptable and they concur in its proposed construction.

2. Purpose - This General Design Memorandum represents a combined Phase I and II post-authorization report. Approval to combine both phases of the report was received from the Office of the Chief of Engineers by 1st Indorsement, dated 5 April 1976. The purpose of this report is to present an objective reassessment of the authorized North Nashua River Channel rehabilitation Project and to reaffirm the project as authorized or to update the project plan to reflect any changed conditions. It also includes engineering data considered in sufficient detail to serve as a basis for approval to proceed with plans and specifications and construction of the restoration project.

3. Scope. This memorandum covers the entire mainstem channel improvement project including general data on the components, functions, costs and benefits, as well as any deviations from the authorized plan dictated by changed conditions and criteria since project authorization. Also presented is the implementation schedule and the operation and maintenance requirements of the local protection works.

C. PROJECT AUTHORIZATION

1. Authorization - A comprehensive plan for development of water resources of the North Nashua River Basin, a principal tributary of the Merrimack River, was authorized by 1966 Flood Control Act substantially in accordance with Senate Document 113, 89th Congress. The plan provides for construction of a coordinated system of reservoirs and local protection projects for flood protection, water supply, recreation and allied purposes.

Restoration of the North Nashua River Local Protection Project was specifically authorized under Title II, Section 203 of the 1966 Flood Control Act in accordance with the recommendations of the Chief of Engineers in Senate Document Numbered 113, Eighty-ninth Congress,

2. Assurances - The project is located on the North Nashua River in Fitchburg, Worcester County, in the northcentral section of Massachusetts about 40 miles west of Boston. The authorized project consists of the restoration of existing walls and cribs, channel clearing, bank and slope protection and removal of obstructions along 4.4 miles of the original project length. The city of Fitchburg, through the Commonwealth of Massachusetts, in return will provide the following assurances:

a. Provide, without cost to the United States, all lands, easements, and rights-of-way necessary for the construction and maintenance of the project.

b. Hold and save the United States free from damages due to the construction work, except where such damages are due to the fault of the United States or its Contractors.

c. Maintain and operate the project after completion, and

d. Provide without cost to the United States all alterations and replacements of existing utilities where necessary.

The list of assurances were presented to the public at a Public Meeting conducted in Fitchburg, Massachusetts on 5 October 1976. Attachment A-2 contains a Resolution dated 15 December 1976 in which is stated in part that the Fitchburg City Council favors the Channelization Project and requests that funds be made available for a complete restoration, starting at the West Fitchburg Wastewater Treatment Plant, following the natural course of the river to the East Wastewater Treatment Plant.

D. EXISTING FLOOD CONTROL PROJECTS IN THE NASHUA RIVER BASIN

1. General - There are no authorized Federal flood control reservoirs in the North Nashua River Basin and no existing Federal reservoirs affect flood levels in the basin. The proposed North Nashua River channel rehabilitation project is the only local protection project in the basin. } Not true!

2. Existing Local Protection Project at Fitchburg - The existing protective works at Fitchburg were constructed following the disastrous flood of March 1936. The project extends along 4.4 miles of the North Nashua River from Cowees Dam (since removed) upstream of Oak Hill Road, downstream to the Fitchburg-Leominster Airport on Falulah Road just above the Leominster town line. The project was built in 1937 at a total cost of $1,370,000. At several places earth banks were protected with concrete crib walls; at other locations the riverbed and toes of the banks were protected against scour by grouted riprap. The work included channel enlargement, relocation of the outlet of Punch Brook, and removal of several abandoned dams. Under the assurances of local cooperation, the city of Fitchburg is responsible for operation and ordinary maintenance of the existing protection. Damages prevented and attributable to the Fitchburg Local Protection since its completion in 1937 are estimated at approximately $4,800,000, or more than four times its initial cost. The existing project has physically deteriorated to the extent it no longer fulfills its design function.

3. Emergency Flood Relief Work - Significant losses occurred on the North Nashua River during the floods of 1955. Under the disaster relief authority of Public Law 875, 81st Congress, as amended, the Corps of Engineers restored the channel in some areas to its preflood condition, but no permanent improvements could be made under this authority. Gravel deposits and debris were removed from the streambed and washed out river bank slopes were filled. No repairs were made to deteriorated concrete cribbing.

4. Emergency Bank Stabilization - Emergency repairs to the deteriorated concrete crib walls downstream of the River Street and Circle Street bridges were authorized for construction under Section 5 of the 1941 Flood Control Act, as amended by Public Law 99, 84th Congress in 1966. Some 2,300 cubic yards of stone protection was placed in the areas where crib walls were failing and the work was accepted by the city of Fitchburg in March 1966.

5. Improvements by Other Federal and Non-Federal Agencies - No other Federal agencies have constructed projects for flood control or other beneficial use of water in the North Nashua River Basin. There are no existing projects for flood control or related purposes for the study area by non-Federal agencies.

E. LOCATION OF PROJECT AND STREAM CHARACTERISTICS

1. Project Location - The Channel Rehabilitation Project is located on the North Nashua River within the limits of the city of Fitchburg, Massachusetts. The project consists of twenty three (23) miscellaneous work items which commence at river station 347+00 and extend to river station 580+00+. The project work sites are within the developed and built-up area of the city and are in most instances in confined areas.

2. Description of North Nashua River Basin, Location and Extent - The North Nashua River Basin is situated in north central Massachusetts in the northern portion of Worcester County and northwest Middlesex County. The area comprises the entire basin encompassing three cities and seven towns lying wholly or partially within the basin. The largest urban area, Fitchburg-Leominster, is one of ten Standard Metropolitan Statistical Areas (SMSA) in Massachusetts and constitutes the major population center within the basin. The project area is about 40 miles from Boston, 210 miles from New York City and 25 miles from Worcester. The North Nashua River, above the confluence of Baker Brook, conducts some 64 square miles of watershed drainage. Baker Brook, which has its confluence with the North Nashua River northwest of the Fitchburg-Leominster Airport, has a watershed of 20 square miles. About four miles downstream of the airport, a U.S.G.S. gage records the runoff from a drainage area of 107 square miles, of which 11.5 square miles is contributed by Monoosnoc Brook. The total basin area is about 132 square miles.

3. Stream Characteristics

a. Main Stream - The North Nashua River is formed at the confluence of the Whitman River with Flagg Brook in the city of Fitchburg, Worcester County, Massachusetts, at an elevation of 590 feet above mean sea level (msl). The river pursues a generally northeasterly course for about three miles into the center of Fitchburg and then turns to a generally southeasterly course for about eight miles to the U.S.G.S. gage in Leominster, and thence seven miles to its confluence with the Nashua River in the town of Lancaster. The 132 square mile watershed of the North Nashua River all contribute to the Nashua River drainage area of 530 square miles. The Merrimack River, at its outlet on the Atlantic Ocean has a drainage area of about 5,000 square miles.

The slope of the North Nashua River averages about 36 feet per mile through the city of Fitchburg and about 10 feet per mile from Fitchburg to the confluence with the South Branch at Lancaster. The total fall of the river is 365 feet over its 18.2 miles of length.

b. Tributaries - The principal tributaries of the North Nashua River are Whitman River, Flagg, Phillips, Baker and Monoosnoc Brooks. There are also a number of smaller streams in the North Nashua River system. Flagg Brook and the Whitman River form the headwaters of the North Nashua River.

(1) Flagg Brook - Flagg Brook has its source in Crocker Pond (elev. 823 msl) at the Princeton-Westminster town line and flows northward for a distance of about three miles to the headwaters of the North Nashua River. It has a drainage area of about 12 square miles and a total fall of about 230 feet.

(2) Whitman River - The Whitman River has its source in Lake Wampanoag (elev. 1079 msl) in the town of Ashburnham and flows in a southeasterly direction for about nine miles to the headwaters of the North Nashua River. It has a drainage area of 27.5 square miles and a total fall of about 490 feet.

(3) Phillips Brook - Phillips Brook has its source in Winnekeag Lake (elev. 1,126 msl) in the town of Ashburnham and flows generally southward for a distance of eight miles to its confluence with the North Nashua River. It has a drainage area of 15.9 square miles and a total fall of about 600 feet.

(4) Baker Brook - Baker Brook is formed by Falulah Brook and Pearl Hill Brook about 2.5 miles above the North Nashua River confluence near the Fitchburg-Leominster Airport. Baker Brook has a total drainage area of 20 square miles of which 11 square miles are drained by Falulah Brook and four square miles by Pearl Hill Brook.

(5) Monoosmoc Brook - Monoosnoc Brook rises in Rocky Pond in the hills west of the city of Leominster and flows in a general easterly direction for 8.7 miles through the business center of Leominster to its confluence with the North Nashua River about nine miles upstream of the junction of the North Nashua and Nashua Rivers. The drainage area at the mouth of the brook is 11.5 square miles. The brook has a total fall of about 550 feet.

F. HYDROLOGY

1. General - A hydrologic analysis for the North Nashua River channel rehabilitation project in Fitchburg, Massachusetts was accomplished for use in project design.

The updated hydrologic data is presented in attached Appendix I.

In the project analysis it should be noted that the channel rehabilitation element was part of an overall comprehensive flood control plan for the North Nashua River Basin. The other flood control projects consisted of constructing four dams and reservoirs, namely, Monoosnoc, Nookagee, Phillips and Whitmanville, plus channel rehabilitation in two tributary brooks, the Baker and Monoosnoc. The standard project storm will produce a peak flow of 20,000 cubic feet per second on the river at Fitchburg. With the proposed system of the four dams and reservoirs the Standard Project Flood would be reduced to 9,000 cubic feet per second. The new channel rehabilitation project will basically restore the integrity of the channel to its original design capacity of 9,400 cfs which is approximately equivalent to the discharge of the March 1936 flood of record. The rehabilitative work will not markedly change the hydraulic character of the channel and if the work is not accomplished it is considered that during flood events emergency measures would be taken by dumping rock on the riverward side of walls and embankments to provide protection and reinforcement. This would further encroach on the hydraulic capacity of the channel and increase design flood levels from about one to three feet depending on the location. In analyzing the benefits of the proposed rehabilitation work, it was assumed that such an increase in flood profiles would be prevented and the integrity of the existing facilities insured to design capacity by the proposed works.

G. GEOLOGY AND SOILS.

1 Regional Geology and Topography - The North Nashua River flows through the Worcester Plateau section of Massachusetts, a broad, maturely dissected upland of moderate relief which is underlain by crystalline rocks. It is a region of rough, irregular hills and ridges which rise in generally steep slopes above relatively narrow valleys. Glaciation has modified the rough topography by smoothing the crest of the hills, steepening some of the slopes and filling the valleys. A generally thin mantle of till blankets the bedrock hills and ridges. The till also occurs in the valleys under thick and extensive outwash deposits which form wide, flat floodplains and prominent terraces along the lower valley slopes. Bedrock outcrops through the till in generally widely scattered areas on the hills and locally in valleys where the streams have uncovered bedrock spurs on the preglacial valley walls. The bedrocks of the region consist of a series of folded late Paleozoic crystalline rocks, mainly granite and gneiss with schistose rocks of several types. The folds trend generally north-south.

2. Surficial and Subsurface Investigations - Investigations at the North Nashua River Project were made in June 1977 and consisted of a reconnaissance, three test borings, and two seismic lines. The location of these borings and seismic lines are shown on Plates 5 through 7. Logs of the borings are discussed in Section D.

3. Overburden - At the project site the North Nashua River flows in a channel over deposits of glacial outwash and ice contact deposits composed of sorted and stratified deposits of sands and gravels. In the easterly portions of the work prominant alluvial and river terrace deposits are evident above the stream channel. These deposits are primarily comprised of sand and silt with minor amounts of gravel, clay and organics generally moderately sorted and stratified. Channel excavations for prior projects, man-made fills and filling of previously eroded stream meanders by postglacial alluvium and artificial fills make the overburden conditions highly variable in depth and material content throughout the project area.

4. Bedrock - Four different bedrock formations are crossed by the North Nashua River in the project area. These formations from west to east are the Fitchburg Granite, Boylston Schist, Worcester Phyllite and the Paxton Quartz Schist. Limited bedrock exposures occur along the stream channel where the eroding stream has uncovered bedrock spurs. These are normally located in areas of the steeper stream gradients. One boring FD-1 encountered bedrock. The rock sampled was a coarse grained diorite considered to be a rock type within the Fitchburg Granite formation. This rock is generally hard and dense providing a good foundation for concrete structures.

5. Seismicity - The project is located in Zone 2 on the seismic risk map accepted by the Coastal Geodetic Survey. There may be possible moderate damage to structures in Zone 2 areas. In accordance with Engineering Technical Letter No. 1110-2-190 dated 21 October 1970, hydraulic structures in Zone 2 will be designed to withstand earthquake accelerations of 0.1g.

6. Foundation Conditions

a. General. In general, except in Area Q, the project features will be built along the riverbank through an area of artificial fills that extend from the top to the toe of the riverbank, ranging from 10 to 15 feet in height. The natural foundation soils beneath the artificial fills consists of highly varied depths of stratified outwash deposits of sand and gravel overlying bedrock. The depth to bedrock throughout the project is highly varied with limited bedrock exposure. In area Q, the right bank of the river cuts into a high step side hill with bedrock exposed at the downstream end of this reach. The location of the work sites and details are shown on Plates 1-4.

b. Concrete Structures. Concrete retaining walls will be built to replace about 500 feet of deteriorated concrete crib walls located in areas "F" and "O". The foundations of these new walls will extend about 5 feet below the riverbed, and will be at or below the foundation elevation of the crib walls they are replacing. In area "P", about 300 feet of concrete wall will replace a demolished building foundation wall along the left bank. In this area the retaining wall will be founded on very compact gravelly silty sand (FD-2).

In area "Q", an existing concrete crib wall will be faced with a reinforced concrete facing anchored to the existing cribbing. In this area, seismic survey lines were run along the axis of the crib wall to establish the presence or absence of shallow bedrock. The surveys, confirmed by boring FD-3, show at least 30 feet of overburden behind the crib wall, except at the extreme downstream end where bedrock is exposed. This information helped determine the type anchorage used to tie the new wall to the old. A rock anchor system independent of the crib wall had been considered provided bedrock proved close to the surface.

c. Gabion Walls. In area "A, a gabion type retaining wall will be built where area restrictions prohibit the use of a cut slope. The foundation below the river bottom consists of a thin layer of silty gravelly sand overlying bedrock. (FD-1).

d. Channel Slope Rehabilitation. In area "A", channel rehabilitation consists of flattening the channel slope where space permits, otherwise a gabion type retaining wall will be built. The riverbank materials consist of about 15 feet of man-made fills overlying a thin deposit of silty gravelly sand at the river bottom overlying bedrock (FD-1). The man-made fill is highly variable consisting of layered deposits of loose sand, gravel, cinders and ashes.

7. Foundation Design

a. General. The surface deposits of man-made fills bordering the river channel are highly variable and are not considered suitable foundation materials for concrete structures. The underlying deposits of silty sands and gravels ranging from moderately compact to very compact are considered ideally suited for foundation design. Since all of the work in the rehabilitation program is in channel and channel slope rehabilitation or reconstruction of retaining walls (there are no dikes or floodwalls involved), through seepage is not a design consideration. Slope protection will be required on the channel slopes to prevent surface erosion.

b. Cut Slopes. The channel side slopes in area "A" and in area "X" will be flattened and regraded to a 1 vertical on 2 horizontal. The channel slope is about 15 feet high in area "A" and contains varying deposits of man-made granular fills, cinders and ashes. In area "X", the slope is about 13 feet high and contains random fill material placed under the original project construction. A 1 on 2 slope is considered satisfactory in this type of material. The cut slopes will be protected from erosion with a 36-inch layer of stone protection on a two layered filter. See Paragraph c for design of slope protection and filters.

c. Rock Slope Protection. The sizing of rock slope protection was based on a D50 size at 1.5 feet, determined under criteria set forth in Engineering Manual EM 1110-2-1601 "Hydraulic Design of Flood Control Channels". A two layered filter was designed under the criteria of EM 1110-2-1901 "Seepage Control". The rock slope protection and bedding stone layer shall consist of quarried rock. The gravel bedding shall consist of bank run gravelly sand and/or sandy gravel. The gradation and layer thickness of the rock slope protection and filter materials are listed below.

Rock Slope Protection
(36-inch layer)

Percent Lighter by Weight (SSD)	Limits of Stone Weights LBS
100	700-1500
50	300- 500
15	100- 250

Bedding Stone
(12-inch Layer)

Sieve Size (U.S. Std)	Percent Passing by Wt (SSD)
8"	100
4"	50 - 90
2"	15 - 45
3/4"	0 - 5

Gravel Bedding
(12-inch Layer)

Sieve Size (U.S. Std)	Percent Passing by Wt (SSD)
6"	100
3"	20 - 100
1"	50 - 90
#4	30 - 60
#40	10 - 35
#200	0 - 10

d. Foundations for Concrete Structures.

(1) Concrete retaining walls in areas "F" and "O" will be built to replace deteriorated concrete crib walls. The base of the walls will extend 5 feet below the riverbed to prevent undermining by scour and as such, will be at or below the bottom of the crib walls they are replacing. Foundation settlements are expected to be negligible.

(2) In area "P", a concrete retaining wall will be built to replace a demolished building foundation wall. The base of the wall will extend about 5 feet below the bottom of the riverbed and be founded on very compact gravelly silty medium to fine sand. Foundation settlements are expected to be negligible.

(3) In area "Q", a reinforced concrete wall will be anchored against the face of an existing concrete crib wall. The new wall will extend to the bottom of the existing crib wall and be founded on either bedrock or compact silty sandy gravel overlying shallow bedrock. Foundation settlement is expected to be negligible.

e. Foundation for Gabion Walls. The gabion wall constructed in area "A" will be founded on either bedrock or a thin layer of silty gravelly sand overlying shallow bedrock. A filter layer of crushed stone will be placed under and behind the gabions to prevent migration of the base material fines through the wall. It is expected that rounded cobbles salvaged from the removal of concrete crib walls will be used to fill the gabion cages. Foundation settlement is expected to be negligible.

H. CURRENT NEEDS AND DEVELOPMENT OBJECTIVES

1. General - The rocky and steep slopes of the valley in the upper reaches of the basin are conducive to rapid runoff subjecting the built up area of Fitchburg to severe flooding which has produced heavy flood damages by inundation, erosion and deposition of debris.

Of paramount interest to the basin economy is the ever present possibility of disastrous flooding in the Fitchburg business and industrial areas from flows exceeding the present capacity of the existing channel. In the early 1960's the officials of the city of Fitchburg became alarmed at the hazard from possible collapse of riverbank local protection structures through undermining at broken, grouted riprap areas and where progressive deterioration of concrete crib walls has reached an advanced stage. If deterioration continues unchecked, obstruction of the river from wall failures will aggravate the flood problem.

The existing local protection project at Fitchburg was originally designed for the record flood, or a discharge of about 9,000 cubic feet per second (cfs). During the floods of September 1938 and October 1955 flood waters nearly overtopped existing improvements arousing local concern as to the adequacy of the project.

As further background, on 13 November 1962, a public hearing with respect to flood control and allied purposes for the study area was held in Fitchburg. Approximately 50 persons attended, including representatives of Federal, State and municipal governments, industrial and agricultural interests, civic organizations, and interested individuals. Municipal officials and industrial leaders of Fitchburg expressed the need for the restoration of the existing local flood protection project as well as other flood protection measures, and for resource development to meet needs for water supply, recreation, and water quality control. The Massachusetts Department of Natural Resources, through its Water Resources Commission, expressed a strong desire for improvements for flood control and allied purposes and for development of related water resources, including water supply, general recreation, and fish and wildlife resources.

2. Discussion of Problems and Needs - The North Nashua River Local Protection Project is an integral part of the comprehensive water resources development plan for the North Nashua River Basin. Within the basin, over 2,800 acres of valley area have been subjected to heavy losses due to floods, four of which have occurred within the past 40 years. The basin is a center of industrial and commercial areas critical to the economy of central Massachusetts. The serious consequences of any additional flooding of past magnitudes would gravely retard the current progress of the economic and social well being of Fitchburg. A recurrence of the record 1936 flood under current economic conditions would cause losses of $43,500,000 in the North Nashua River Basin.

The North Nashua River Local Protection Project serves as an important element in conjunction with the reservoirs and remaining local protection projects toward effecting this significant reduction in flood damages. The improvements to the channel will insure that the channel can safely pass 9,000 cfs, cubic feet per second.

The proposed system of reservoirs has been modified since the basin plan was authorized in 1966 but the revised plan still includes a restored channel through Fitchburg capable of handling 9,000 cfs.

On 5 October 1976, a public meeting was held by the New England Division in Fitchburg to inform all concerned about the scope of the channel restoration project and to determine if there were any problems or needs which should be addressed during our reassessment of the authorized project. The majority of those present were in favor of the restoration project. Several spokespersons indicated the Conservation Commission River Subcommittees desire to provide a greenbelt and passive recreation areas along portions of the North Nashua River within Fitchburg.

In response to these requests, another meeting was held on 17 November 1976 to discuss a greenbelt and riverside path system along the North Nashua River as proposed by the city of Fitchburg, Massachusetts. The purpose of the meeting was to bring together Federal, State and local agencies to discuss means for developing the greenbelt, particularly since the Corps has limited authority for recreation development within the present scope of the North Nashua River Local Protection Project.

The meeting was opened by restating that the restoration project as authorized does not provide for recreational development within the purview of this project. However, solutions for specific problem areas along the river may be designed to facilitate rather than preclude full development of the proposed greenbelt by the city of Fitchburg,

The planned channel improvement program as proposed by the Corps and its relation to the proposed greenbelt was outlined. Emphasis was placed on the fact that each planned flood protection improvement is a preliminary proposal only, Possible design modifications to facilitate greenbelt development by the city of Fitchburg were described in concept only, to illustrate ways in which the Corps could provide assistance within the scope of its present authority. Types of modifications described included terracing of some walls to provide a potential path right-of-way, texturing of concrete structures for visual interest, revegetation of construction areas, and grading of Contractor access roads for later pathway use.

A group discussion with the various agencies in attendance provided information on numerous potential sources of funding assistance available to the city of Fitchburg. The Environmental Protection Agency 208 Program provides funding to regional planning agencies, such as the Montachusett Regional Planning Commission, to develop water quality management plans. These plans include the examination of means to guide riverbank use to support the objective of water quality improvement. The Bureau of Outdoor Recreation (BOR) has several programs to provide matching fund grants for recreation development, including use of the Land and Water Conservation Fund. In addition to BOR, the Commonwealth of Massachusetts has a matching fund program for recreation development which currently is placing a priority on urban areas.

At the conclusion of the 17 November 1976 meeting, it was agreed that the Corps would proceed with its present plan of limited channel improvements at select locations along the river, and design considerations would be made where possible to accommodate later development of a greenbelt by others. The city of Fitchburg would be responsible for planning, coordinating, financing and completing the proposed greenbelt. A resolution by the Fitchburg City Council supports this posture.

I. FLOOD CONTROL ALTERNATIVES - LOCAL PROTECTION

1. General - As part of this project reevaluation all practicable means of solving the flood control problems in the overall study area were reconsidered. The local protection works in the city of Fitchburg was only one of the many projects deemed necessary to alleviate the total flooding problem. Inasmuch as the project is a rehabilitation of existing local flood protection facilities no other structural alternatives were considered.

2. Discussion of Nonstructural Alternatives - The possibility of nonstructural measures were investigated and an analysis of nonstructural types of alternatives is as follows:

Alternative No.	Plan	Comment
1	No-Action	The "no action" plan would be to leave the existing project in its present condition of disrepair and with physical obstructions to river flow. There would not be any monetary costs involved, however, such a course of action would be unsuitable and not be an aid in reducing flood problems.
2	Evacuation of Floodplain	The removal of all existing development in the floodplains of the Fitchburg area would cause tremendous disruption of human needs and resources. It would cause adverse social and institutional effects associated with large scale relocation and the cost, although not estimated, would be exorbitant. Such a plan would eliminate the need for channel improvements.
3	Floodplain Management	This plan would greatly reduce further encroachment on floodplain areas, however, it does not protect the highly developed areas of Fitchburg against floods. The floodplain in the city is predominantly commercial and industrial with large content values. (i.e.: raw materials, equipment and manufactured goods).
4	Floodproofing and Evacuation	This alternative provides individual type flood protection for some properties and areas. However, areas and bridges, roads, etc., between the protected buildings would remain subject to flooding, siltation and debris deposition. It does have potential application for some individual properties but not for flooded areas as a whole.
5	Flood Insurance	This non-structural alternative was not evaluated.

Due to the congested built-up area of the city floodplain which mainly comprises a commercial and industrial development, it is considered that the above possible nonstructural alternatives are not totally feasible, acceptable or suitable.

3. Discussion of Channel Rehabilitation - In reality the Channel Rehabilitation project is an alternative and the most acceptable from the following points of view:

It involves the accomplishment of physical improvements to an existing accepted project.

Causes minimum environmental, social-economic impact and disruption to existing private and public facilities, enterprises, etc.

Improvement Costs are not excessive and the Benefit-Cost Ratio of the project is favorable and above unity.

Offers reduction of losses from flooding.

4. Conclusion - The channel rehabilitation project has been the authorized project since 1966 and is the "selected" plan of prior studies and consideration of other type alternatives. An updated review of the project has been made and it is considered that the channel rehabilitation of the original 1936 project as constructed by the Corps of Engineers remains sound and should be accomplished.

J. DESCRIPTION OF PRIOR AUTHORIZED PLAN

1. General - The North Nashua River. Channel improvement and rehabilitation of the existing walls and cribs will extend for a distance of five miles. This work will provide a channel with a safe carrying capacity of 9,000 cfs. The work includes channel deepening, bank and slope protection and removal of obstructions. Due to high channel velocities during flood periods, banks will be protected to prevent erosion and consequent deposition in the improved channel. The plan which contains four primary features has a total estimated cost of $700,000 (June 1964 Price Levels).

2. Work Features Are as Follows:

(1) Walls and Cribs

Sites 1 and 2 - River Street Bridge - two areas downstream of bridge abutment walls.

Site 3 - Circle Street - immediately downstream of the bridge.

Site 4 - Vicinity of General Electric Company - upstream of Putnam Street.

Sites 5 and 6 - Laurel Street - upstream and downstream of the Boston and Maine Railroad Bridge,

Site 7 - Immediately upstream of Water Street Bridge.

(2) Rehabilitation of slope protection - Restoration will be made of grouted riprap toes at bridge piers, wall footing, and at other critical locations. In various areas from Oak Hill Bridge downstream to the Falulah Road bridge, existing deteriorated riprap will be replaced with stone protection of adequate size.

(3) Channel excavation - Since the completion of the Work Relief Project in 1937 there has been considerable deposition at various locations along the 4.4 mile reach of the river. In addition to these deposits, several restrictions produced by bridge piers and the alignment of the channel have reduced the effective capacity of the channel. Because of the excessive cost that would be involved in changing the alignment of the channel or widening the channel at bridges, limited channel deepening will be accomplished to accommodate flood flows.

(4) Removal of Channel Obstructions and Depositions. Boulders, stone and debris now obstructing the channel will be removed. Movement of stone has been caused by past floods. Deposition of this stone impedes channel flows by greatly increasing friction values along the channel. The plan of improvement calls for the removal of this stone and replacement of riprap where necessary. Stone slope protection will be provided to prevent further erosion and undermining of the banks during future floods. A Approximately 3,500 cy of stone would be removed and restored on the channel bottom and side slopes.

Deposits of silt, sand and gravel accumulated from Oak Hill Road downstream to Falulah Road, reduce the effective capacity of the channel and the flow capabilities of the stream. Removal of deposition where required will be accomplished.

3. Summary of First Costs, Annual Charges and Benefits - The summary of First Costs, Annual Charges and Benefits for the North Nashua River local protection project is as follows:

SUMMARY OF COST, ANNUAL CHARGES AND BENEFITS*
(June 1964 Price Level)

First Costs	
Federal	$ 700,000
Non-Federal	0
Total First Costs	$ 700,000
Annual Charges	
Federal	$ 27,900
Non-Federal	7,000
Total Annual Charges	$ 34,900
Annual Benefits	$ 40,000
Benefit-Cost Ratio	1.2

*Based on 50 year project life, 3-1/8 interest rate.

K. POST AUTHORIZATION STUDIES

Subsequent to authorization of the project in 1966 various efforts were performed to reaffirm and/or to reformulate and update the scope of the channel restoration. The additional studies, tasks performed, and meetings held are described as follows:

1. Project Scope - Basic planning decisions made in the survey stage have been reviewed, updated and supplemented by field surveys and conferences with local officials. Project coordination has been maintained with other governmental and state agencies as well as local interests. Environmental impacts, and effects of the flood control works, project features and cost estimates have been reviewed and updated to reflect the changing needs and desires of the community and the changing economic conditions.

2. Hydrologic Studies - Previous investigations were reviewed, updated and supplemented with additional data developed based on current site conditions. Detailed hydrologic analyses have been made to determine stream flow, flood development, and project design flood elevations. The methodology and results of these studies are presented in Appendix I, Hydrologic Analysis.

3. Economic and Damage Surveys - Previous flood damage surveys done during the survey stage (1962) were updated to reflect changed conditions. Recent field investigations revealed extensive changes and developments have occurred in recent years. Detailed analysis of potential flood losses and damages have been made and flood prevention benefits have been recently revised and updated accordingly.

4. Lands and Damages - Appraisals of lands and damages previously determined have been reviewed and updated in accordance with present site conditions and current real estate values in the project area.

5. Environmental and Economic Social Assessment - An environmental assessment including social-economic aspects has been prepared and is included in this memorandum.

6. Workshop Meetings. Meetings were held with the Fitchburg Conservation Commission, city of Fitchburg's Planning Department and various Federal and State agencies to assure that the proposed channel restoration project and the city's plans for a linear greenbelt were integrated where possible. Coordination with other State and Federal agencies was established to maximize their participation in the greenbelt plan.

7. Public Meeting - A public meeting was held in Fitchburg, Massachusetts on 5 October 1976 to exchange information concerning the authorized restoration project and to procure the objectives and needs of interested parties as well as their preferences regarding alternative methods of restoring project features.

Approximately fifty persons attended the public meeting. Seven spoke or participated in the discussion including State and city officials. A written statement submitted by Madeleine Gaylor on behalf of the Fitchburg Conservation Commission praised the cooperation of the Corps and expressed support for the project. Mrs. Gaylor expressed the desire that the Corps accommodate the Commission's greenbelt plan wherever possible. No adverse statements were made but those who did speak urged the Corps to provide whatever assistance they could for implementing the greenbelt plan.

L. PLAN FORMULATION

1. General - The principal purpose for rehabilitating the existing North Nashua River Local Protection Project in Fitchburg, Massachusetts is to restore the deteriorated channel to its original 1937 capability of safely passing a flood volume of 9,000 cubic feet per second.

As mentioned in Section B the location of the proposed upstream reservoirs and dams has been altered and no final decision has been made on these projects to date. Regardless of the status or final outcome of the proposed reservoirs, the overall flood protection plan for the North Nashua River Basin still requires a restored channel through the center of the city of Fitchburg.

Alternatives to the channel rehabilitation have been discussed in Section I. The alternatives considered nonstructural measures such as "no action", evacuation of the floodplain, floodplain management, floodproofing and evacuation. In summary, the various nonstructural options were not totally feasible or acceptable and the rehabilitation of the channel was the most suitable and therefore became the "selected" plan. Restrictive zoning measures or evacuation of the floodplain is impractical due to the highly developed nature of the floodplain.

2. Extent and Character of Flooded Area in Fitchburg - The previous paragraph reiterated the purpose of the project and before proceeding with a discussion on the channel improvements it is felt that further mentioning of the extent and character of the flooded area in Fitchburg would serve as a reminder of what the channel project will assist in protecting.

Over 2,800 acres of flood-prone land lies along both sides of the North Nashua River and two of its larger tributaries, Baker Brook and Monoosnoc Brook, between Snows Mill Pond in Fitchburg and its confluence with the Nashua River in Lancaster. The floodplain in the lower reaches of the river in Lancaster and in the lower end of Leominster is principally meadow and swampland. The plain is increasingly built over as one goes upstream in Leominster and in the city of Fitchburg, and with the exception of the mile of river which borders the airport in Fitchburg just north of the Leominster line, the plain is completely built over.

The riverfront area in Fitchburg is completely developed with light and heavy industrial concerns, commercial establishments and tenement type housing. The main line of the Boston and Maine Railroad's Fitchburg Division follows the river valley through Fitchburg, crossing the river or its tributaries at nine points within the city and much of its trackage is also subject to flooding.

Industry established itself along the North Nashua River early in the 1800's being attracted first by the waterpower available and later by the availability of process water. Today, paper making, turbine manufacturing and the production of building hardware and carpentry tools account for a large segment of the total industrial employment with machine shops, foundries, textile plants and plastic manufacturing plants accounting for the balance. Much of this industry is located in the flood-prone portion of Fitchburg along the main stem of the river. Over 800 acres of land is in this floodplain. The extent of the flood plains in both Fitchburg and downstream Leominster are illustrated in New England Division report entitled: "Flood Plain Information, North Nashua River, Fitchburg & Leominster, Massachusetts, April 1977".

3. Discussion of Channel Improvements - The detailed work involved in the channel restoration are shown on Plates 1, 2, 3 and 4 with further descriptive data in Section P. A more generalized description of the overall project and some of the reasons for the channel improvements in the North Nashua River in Fitchburg are as follows:

Channel improvement and rehabilitation of the existing walls and cribs will extend for a distance of five miles. This work will provide a channel with a safe carrying capacity of 9,000 cfs. The work includes channel deepening and reshaping, bank and slope protection and removal of obstructions. Due to high channel velocities during flood periods, banks will be protected to prevent erosion and consequent deposition in the improved channel. The plan has a total estimated cost of $2,100,000 and major items are:

(1) Concrete Walls and Cribs.

(2) Rehabilitation of Slope Protection

(3) Channel Excavation

(4) Removal of Channel Obstructions and Depositions

NOTE: These major items have been discussed in detail in previous Section J.

4. Project Formulation Considerations

a. Engineering and Construction - The work involves the rehabilitation of an existing project and additional real estate acquisitions are not necessary. The width of the channel and its alignment will remain unchanged.

Constraints which limited the original channel improvement project such as the 26 bridges over the river and the numerous factories which are on the edge of the riverbank still exist today. Further constraints are imposed on rehabilitation by the presence of a 45" sewer pipe which weaves its way down along the river to the East Fitchburg Treatment Plant. This sewer crosses under the stream at about six locations and occasionally runs in and parallel to the streambed, necessitating extreme precautions during the construction period.

These noted constraints practically eliminate the formulation of feasible structural alternatives other than rehabilitating the channel. When the upstream reservoirs were planned, alternatives were proposed which provided a large tunnel structure through the city which would in essence preclude the need for upstream storage and channel rehabilitation. This alternate was extremely expensive and not considered economically feasible.

The rehabilitation of the channel as proposed in the memorandum is considered the most acceptable alternative for providing the desired degree of flood protection and assuring a flood flow of 9,000 cubic feet per second. The project is also feasible from the institutional point of view in that it is acceptable from the local and State points of view.

b. Environmental Considerations - The project will not produce any long-term environmental or water quality problems. Short-term environmental problems such as turbidity in the water during construction operations will be realized but be of short duration.

The project will increase esthetic and visual amenities of the river and will be conducive to construction of pathways and trails by others along the river where donditions permit.

In view of the recent completion of the two wastewater treatment plants in the city of Fitchburg and since the water quality of the stream has commenced to improve, it is felt that the channel restoration project is very timely and will lend to improving of the environment in the area and also the social aspects of the inhabitants.

c. Economic Considerations - The rehabilitation project will benefit the local population and industrial climate by reducing possible damage from flooding. The flood protection to the various factories, public facilities such as bridges and roads, commercial and residential areas will be greatly increased. The rehabilitation has

less adverse impact than other alternatives considered such as flood-proofing, evacuation of the floodplain, etc. In addition the estimated annual cost of $5,400 to the city for maintenance after completion of the project should not constitute an undue financial burden.

5. Conclusions - After all factors were considered it is concluded that structural rehabilitation of the channel is the most economically feasible and socially acceptable alternative.

6. Application of Federal Planning Criteria - During the time period between the completion of the project Survey Scope Report in January 1965 and the present, numerous changes in planning procedures and new Federal criteria in connection with objectives, plan formulation and addressing environmental impacts have come into being. In view of this a review of the project has been made to determine which criteria the project complies with. Comments are as follows:

a. The General Design Memorandum does not address the Water Resources Council Principles and Standards in entirety for the following reasons:

(1) The General Investigation Survey Scope Report was authorized in Resolution by the Committee on Public Works, United States Senate, adopted 9 February 1961, and completed on 25 January 1965.

(2) The channel improvement project was authorized by the Flood Control Act of 1966 and prior to 25 October 1973. It is a rehabilitation of a previously authorized Federal Project in 1936.

(3) The scope and purpose of the project has remained unchanged since the Survey Scope was accomplished.

(4) It is considered that since the time the Survey Report was prepared and the present when the General Design Memorandum is being prepared, that there has been no significant change in the project area to require reformulation of the authorized plan or cause different impacts thereto. The original plan remains valid.

b. The project was developed in accordance with Senate Document 97 dated 29 May 1962 and Senate Resolution 148 dated 28 January 1958.

c. An up-to-date assessment of the environmental, economic and social effects of the project has been made and is included in this General Design Memorandum. It is considered that the contents of Section 122, Public Law 91-611 and the National Environmental Policies Act of 1969 have been addressed.

M. COORDINATION

1. General - During the course of the Advanced Engineering and Design investigation, measures were taken to provide for public participation by agencies of Federal and State Government, by the city of Fitchburg and by civic groups and interested individuals. Several workshop meetings and a public meeting were held to insure that the needs and desires of the public were incorporated in our reassessment of the authorized plan.

2. Coordination With Other Agencies - Coordination with the following agencies and groups was maintained throughout the study:

Federal Agencies

Department of the Army
Department of Agriculture
Department of the Interior
Department of Housing and Urban Development
Environmental Protection Agency

Massachusetts Agencies

Department of Community Affairs
Department of Conservation Services
Bureau of Outdoor Recreation
Department of Environmental Quality Engineering

Local and Regional Groups

Nashua River Watershed Association
Fitchburg Conservation Commission
City of Fitchburg

The Nashua River Watershed Association consists of members, representing the cities and towns located wholly or partly in the watershed. Close coordination has been maintained with them and also with the Fitchburg Conservation Commission. The groups have furnished assistance to the Corps by helping in the decision making process by making known the desires of watershed interests.

3. Summary of Views -

On 7 August 1977 the New England Division wrote the city of Fitchburg to determine their views on whether the Corps should continue with designs and ultimate construction of the project; also, to determine if the city would be willing to provide assurance for the project. By letter dated 22 August 1977 the city responded in the affirmative for the Corps to continue work on the project.

On 11 October 1977 Corps representatives made a physical reconnaissance of the river with members of the Conservation Commission for the purposes of viewing and determining what types and location of tree growth could remain or would have to be removed during the rehabilitation of the project.

N. SUMMARY OF ENVIRONMENTAL CONSIDERATIONS

Based on review of relevant facts pertaining to the public need and environmental considerations, the conclusion reached is that the rehabilitation of the local protection project should be implemented. The following points were considered pertinent in evaluation of the project:

(1) The negative environmental impacts of the project are considered to be minimal. Prior pollution has eliminated any aquatic species which may have inhabited the river. Therefore, any repair work done will not displace fish or any other aquatic species. Completion of the project will greatly improve the appearance of the area. Revegetation measures will be taken at most locations where the existing vegetation will be removed. This will be carried out at those places where stream flow will not be impeded, or act as a catchment for floating debris which would increase flooding. Therefore, vegetation removal will have a minor impact. (Refer to Appendix II for a detailed description of the environmental factors).

(2) Social well-being must be considered. It would be perilous to allow the present conditions to remain as this would endanger the surrounding areas to severe flood damage.

(3) Any flood damage would have a harsh effect on the economy of the city. In addition to the harm to private property which would cause economic hardships, a flood would damage the mainstay of Fitchburg's economy, namely the industries, with the possible result of a temporary or even permanent shutdown of the plants.

The proposed rehabilitation project has been found to be the only practicable course of action. The environmental impacts that have been considered are minimal and/or short-term. Total public interest has been considered. With all the considerations and alternatives examined, the conclusion reached is that the rehabilitation project should proceed.

Attached Appendix II, Environmental Assessment, contains additional detailed information on the various impacts caused by the project.

Attachment C is a Section 404 Evaluation Report on the project with respect to discharge of dredged and fill material into the stream.

O. ECONOMIC AND SOCIAL IMPACTS ANALYSIS

Planning for flood control requires an understanding of the many diverse forces interacting in the proposed impact (study) area. Moving towards economic growth, housing and industrial development, protection of valuable natural resources, higher or lower taxation, changes in transportation patterns, etc., will affect the quality of life in any particular region. Complex interacting social, economic, and environmental factors may bring about both adverse and beneficial effects to the same community. This flood control program will have social, environmental and economic impacts. Some will be short run, others long run.

Having as much information, and raising as many questions and issues as possible, is essential in order to better examine different alternatives and arrive at those plans which meet most consensus and which may be most practical and desirable. Such plans would capitalize on beneficial effects while minimizing or mitigating possible adverse effects in both the short and long run.

At the 5 October 1976 public meeting, the U.S. Corps of Engineers shared information with the public in an effort to aid groups and individuals in expressing their reactions, comments, suggestions, feelings and questions. The cooperation of the local community, including both support and criticism, is necessary in order for the Corps to reflect actual public needs of the project area in narrowing, eliminating, or modifying the alternative choices.

Fitchburg has a well balanced economic base and accounts for one half of the firms in the Standard Metropolitan Statistical Area (SMSA) 55% of the annual payroll, and 53% of the average annual employment. Manufacturing with 52% of the total employed population accounted for the largest source of employment. The three leading firms, measured in employment, were fabricated metals, paper products and machinery industries (except electrical). Within the watershed area and principally in Fitchburg, paper production amounts to 20% of the total in Massachusetts. In the past ten years, the population in Fitchburg has remained relatively stable; yet the SMSA's population has increased by 8%. Thus the city of Fitchburg is the employment center for a population of approximately 100,000 residing in the SMSA consisting of six cities and towns.

In the past, employment has been hampered by the attraction of many of the region's industries to other parts of the nation. High wages, ever increasing tax burdens, and the high cost of energy and transportation have led to the exodus of manufacturing firms from both the region and State. The unemployment rate during 1976 was 10-1/2% for the SMSA. This was 3% higher than the national average. Therefore, anything that can contribute to the development of employment opportunities in the region should be welcomed.

The positive contribution of the project is the prevention of flood losses. Physical losses include only such losses or damage to structures, machinery and stock, and cost of cleanup and repairs. Nonphysical losses include loss of unrecoverable wages and business costs of temporary facilities, plus increased cost of operation.

Other positive effects can be associated with the proposed project. These could include avoidance of road washouts thus aiding the motorists and travelers, possible additional recreation opportunities, reduction of the probability of injury or death attributed to flooding, the easing of the fear of flooding, protection of water supply and sewage collection systems, prevention of contamination and spread of disease, the availability of jobs and employment opportunity during construction of projects, and help in the maintenance and sustaining of employment.

Such flood protection would result in economic and social enhancement of Fitchburg in particular and the watershed region in general, in the long run. The reduction of damages from floods would yield great economic benefits, especially to industry and may halt the flight of manufacturing jobs. The serious consequences of any additional flooding of past magnitude would gravely retard the current progress of economic improvement and social well-being.

The proposed project would cause temporary local air and noise impacts associated with clearing, grading, and filling operations. Several local streets would experience increased traffic from trucks bringing in materials for construction and removing debris. Such truck traffic would bring corresponding air quality, noise, safety and congestion impacts. Most effects during any project construction tend to be temporary, rather intense and the impact more limited to the specific site location. These impacts are of a temporary nature and should cause only minor inconvenience.

The nonaction alternative shifts the major responsibility and burden of flood protection to those who live and work in the flood-prone areas. Under the no action (do nothing) alternative, no new regional or local structural projects are built as a possible solution to reduce flood damages. No action means forfeiting potential benefits such as construction related jobs, reduced fear from flooding and the long run security of decreased flood damages.

Appendix III contains the Economic and Social Effects Assessment for the channel rehabilitation. In summary, it is considered that the project will not provide any long term adverse economic or social impact in the project area.

P. DESCRIPTION OF PROJECT PLAN

1. General - The recommended plan for rehabilitating the existing local flood protection project in the North Nashua River in Fitchburg, Massachusetts is shown on Plates 1, 2, 3 and 4. Restoring the project to its original 1937 condition will assure a channel capacity of 9,000 cubic feet per second for streamflow. The work does not include any operable structures or equipment such as gates, pump facilities, locks or automatic equipment or devices. In general, the project requires miscellaneous items of work at approximately 23 various locations within the five mile reach of the river.

2. Description of Work Items - In reference to Plates 1, 2 and 3 the specific items of work and their location are designated by an alphabetical letter within a circle. The work items are described in general text form on the lower portion of the general plans which facilitates direct and simple association of the work involved to its location.

The work involved is derived from the original description contained in the Survey Scope Report prepared on 25 January 1965 with updating based on existing conditions detected during recent engineering reconnaissance of the project area.

Following is a description of the work items which will be included in project specifications to supplement the drawings when contract documents are prepared.

NOTE: The description is developed starting at the upstream limits of work in the vicinity of the now removed Cowee's Mill Dam, and proceeding downstream to the Leominster town line below the Fitchburg airport. Bank identification is made looking downstream.

The following restorations are proposed:

a. In Area "A" the existing bank slope is unstable and erosion has been taking place here during flood conditions. The Area "A" new rock and gabion slope protection is located about 720 feet upstream from the Oak Hill Road Bridge at the west end of the James River Mass Inc. building. There will be about 220 feet of new 36" rock slope protection placed on 12" of new filter stone on 12" of new gravel bedding as indicated on Plate 4 typical section. About 110' of this new protection will be supported by a new gabion retaining wall which is also shown on Plate 4 typical section. The new side slope of the rock protection will be 1 on 2 and is approximately 16 feet high. The top of the protection adjacent to the building forms a small dike about 3' high. Remove random boulders in the same region.

b. In Area "B" an approximate 43 foot portion of the cut stone masonry wall has collapsed and the stones have fallen into the river. Also this wall has several loose stones that are broken up and are ready to collapse. This 43 foot portion of the wall is located about 500 feet upstream from the Oak Hill Road Bridge across the river from the west end of the James River Mass Inc. building. The loose stones are to be removed above Elev 495 and the collapsed wall is to be rebuilt to Elev 495. The rebuilt wall will have a top width of 2 feet and a bottom width of 8 feet and will be approximately 10 feet high as indicated on the typical section on Plate 4. Also there is to be backfill at the rebuilt wall. Random stones from the collapsed wall (adjacent to the wall) in the river are to be removed.

c. In Area "C" which is immediately upstream from the Daniels Street Bridge on the South Bank of the river, the masonry cut stone has several feet of cracks in the wall. This cracked cut stone wall will have to be regrouted for a distance of about a hundred feet. Remove shoaling where indicated on Plate 1.

d. In Area "D" which is downstream from the Daniels Street Bridge on the South Bank of the river, the storm sewer outfall discharge is eroding the riverbank. Also, more erosion is being caused by the broken curbing at the edge of the parking area. This curbing will be repaired. A new half-round 18" concrete section will be used to direct the drainage to the riprap. A small amount of new riprap will also be placed here. Also, a few broken boulders immediately downstream of the bridge will be removed. Remove shoaling where indicated on Plate 1.

e. In Area"E" about 30 square yards of grouted cut stone channel bottom has eroded away between Kimball Street Bridge and the B & M RR bridge. This 30 square yard area will be repaired with a new grouted cut stone channel bottom. Remove shoaling where indicated on Plate 1.

f. At Area "F" immediately north of River Street are crib sites Nos 1 and 2 on west and east banks which have been covered with dumped granite riprap. These must be removed to provide for greater channel flow capacity. At crib site No. 1, the crib and riprap will be replaced by a concrete gravity wall with a one foot top width, and a varying height of 8 feet to 15 feet, and a varying base width. The landside back slope is two on one and the front riverside side slope of twelve on one, as indicated on Plate 4. At crib site No. 2, the crib and the riprap will be replaced by a ramp which is designed to accommodate the physically handicapped. The ramp is approximately 135 feet long and it ramps from a top elevation of 486.4 to a bottom elevation of 475. The ramp is made up of two gravity walls and a connecting slab, as indicated on the typical section on Plate 4. The riverside gravity wall has a top width of one foot and a varying base width. The height varies from 19.4 feet to 8 feet. The riverside face of the wall is battered twelve on one and the other side face has a two on one slope. The landside gravity wall is much smaller, having a top width of one foot

and a varying bottom width as indicated on the typical section on Plate 4. The height varies approximately four feet to ten feet. The front face is vertical and the rear face slopes two on one. A six foot wide and six inch deep concrete slab connects the two walls. Where these new walls make contact with the existing concrete walls, they are connected by 1" diameter dowels at 18 inches each way. Remove selectively and/or reposition the large stones in the channel. Shoaling is to be removed in the vicinity of Sta 545 + 00 to Sta 550 + 00.

g. At Area "G" repair the south downstream wingwall at the Sheldon Street Bridge. Also downstream from the bridge, repair the grouted riprap by placing wall graded grouted riprap at the downstream end as indicated on the typical section at Area "L" on Plate 4.

well

h. At Area "H", which is located downstream from the Nockege Street bridge, remove large stones and replace with a well graded riprap or reposition existing stone. Shoaling is to be removed in the vicinity of Sta 527 + 00 to 531 + 00.

i. At Area "I", which is located downstream from the downstream River Street (near West Street), bridge, protect the utility crossing by resetting the large stones creating a uniform face, then inbed well graded riprap around the large stones. Shoaling is to be removed in the vicinity of Sta 522 + 00 to Sta 526 + 00.

j. At Area "J", immediately downstream from the Circle Street Bridge on the east bank is crib site No. 3, the top of which is exposed above the existing riprap. Because the existing riprap is undersized, it must be replaced with new larger size stone graded on a 1 on 2 slope as indicated on the typical section on Plate No. 4. One hundred and thirty feet approximately twelve feet high of the existing stone slope protection will be removed as necessary to provide for a three foot layer of a new larger size stone which will completely cover the existing cribbing. Also, reposition the stones in the river. Shoaling is to be removed in the vicinity of Sta 507 $\pm$ 00 to Sta 508 + 00 and 503 + 00 to 504 + 00.

k. At Area "K", which is located downstream from the Broad Street Bridge on the south bank at the public works maintenance yard, repair approximately 100 feet of wall openings at the base of the wall, which has been eroded away by flood water action.

l. At Area "L", which is located 400' $\pm$ downstream from the Broad Street on the north bank of the river, repair about 125' $\pm$ of flood eroded grouted riprap as indicated on the typical section on Plate No. 4. The new grouted riprap will have a 1 on 2 slope and 2 foot by 3 foot toe at its base.

m. At Area "M" immediately upstream from the intersection of Putnam Street and the Boston and Maine RR bridges on the south bank of the river, concrete crib No. 4 is located. Several of the eroded stretcher members will be resurfaced and a new 2.5 feet by 1.5 feet concrete curb will be doweled to the existing crib for a length of 258 feet. Remove shoaling Sta 487 + 000 to Sta 492 + 00. See Plate 4 for details.

n. At Area "N" which is located on the south bank between the Commercial Street Bridge and the Cushing Street Bridge, cap approximately 325 feet of the concrete and masonry wall so that the top elevations will be the same as the top elevations along the opposite north bank wall. The south wall will be raised from about 2 feet at the Commercial Street Bridge to about 4 feet at the Cushing Street Bridge with about an approximate 3.5 foot average rise in height and a width of 2 feet 3 inches. Selective removal or repositioning of stones in the channel shall be accomplished where indicated on Plate No. 2.

o. At Area "O" are crib sites Nos 5 and 6. Parts of crib No. 5, which is located between the RR bridge and the Laurel Street Bridge on the West Bank, have eroded away and will be replaced by a concrete gravity wall approximately 132 feet long, having a height of 12 $\pm$ feet on one end and a height of 15 $\pm$ feet on the other end. The riverside wall slope is 12 on 1 and the landside wall slope is 12 on 7. The top width is 1.5 feet and the base width varies. The crib No. 6 is located just downstream from the Laurel Street Bridge on the west bank and is partially eroded and will be replaced by a concrete gravity wall, which will tie into an existing drain structure. The wall length is approximately 100 feet long, having a height of 11 $\pm$ feet on one end and a height of 6.0 feet on the other end. The riverside wall slope is 12 on 1 and the landside wall slope is 12 on 7. The top width is 1.5 feet and base width varies. See typical section on Plate No. 4. Remove shoaling under right span of railroad bridge.

p. At Area "P" which is about 500 feet downstream from the Laurel Street Bridge on the north bank of the river, rebuild approximately 110 feet of wall as shown on typical section on Plate No. 4. The new concrete wall is 1.5' wide at the top and 10'-9" wide at the base and is 21'-6" high. The base of the wall is five feet below the channel bottom. The landside face of the wall is vertical. Remove material stockpiled at top of wall and material along base of wall. Remove rubbish on south bank at $\pm$466 + 00. Remove shoaling where indicated on Plate 2. Sandblast wall 310' long - 13' high and paint fence.

q. At Area "Q", which is located on the south bank of the river approximately 800 feet downstream from the Laurel Street Bridge, is crib site No. 7, parts of the concrete members of which have eroded away. The existing crib is to have a new 1.5 foot thick reinforced concrete veneer facing as indicated on the typical section on Plate No. 4. The new concrete facing is to be approximately 250 feet long and approximately 16.5 feet high and will be doweled to the existing crib. The top of the facing is to be 2.5 feet by 1.0 foot thick and the base is to be 4.0 feet by 3.0 feet thick. Temporary access must be constructed in the riverbed to accomplish this project.

r. At Area "S", which is located approximately 850 feet downstream from the private bridge which goes into the Fitchburg Light and Gas Company, there are approximately 50 pieces of excess broken stone boulders which must be reset just downstream of the power service dam.

s. At Area "T", which is about 250 feet upstream from the Fifth Street Bridge, there are two midstream bridge piers which must be removed. Also the bridge abutment on the north riverbank is to be retained but the upper two courses of granite block must be regrouted for safety.

t. At Area "U", which is located about 100 feet downstream from the Bemis Road Bridge, reposition excess broken stone in the riverbed beginning at the downstream toe of the dam.

u. Area "V" is located about 1000 feet upstream from the Falulah Road Bridge and about 2000 feet downstream from the Bemis Road Bridge. At Area "V" the Syphon Dam has been partially washed out by past floods. The new work in Area "V" consists of removing the remains of Syphon Dam, placing new 36" rock slope protection on both adjacent riverbank areas, restoring the outlet of the canal into the river, and adding upstream and downstream rock sills to the channel bottom. As indicated on Plate 4 typical section, the side slopes will be 1 on 2, having 36" rock slope protection on 12", filter stone on 12" of gravel bedding which will go to a top elevation of 350. The new channel bottom elevation will be approximately 338±. The lengths of the rock slope protection will be about 570 feet on the south bank and about 350 feet on the north bank. The channel bottom rock sills will be 20 feet wide and 6 feet deep.

v. Area "W" is the shoaling areas to be removed located upstream and downstream of the Falulah Road Bridge as indicated on Plate 4. The shoaling to be removed goes from ± Sta 347 + 00 to ± 350 + 00 and from ± Sta 354 + 00 + to ± 360 + 00 on the north bank, and from ± Sta 357 ± 00 to ± 361 + 00 on the south bank.

3. Real Estate Requirements

General

The channel rehabilitation project will not require the acquisition in fee or permanent easement of any additional lands to construct the project. All permanent construction work is within the limits of the original real estate interests of the original local protection project authorized in 1936 and for which construction was accomplished and completed by the Corps of Engineers in 1937. Likewise, there are no anticipated costs involved for Severances, mineral or crop damages, water rights, relocation of persons or businesses.

Access

Access to some of the specific work sites in some cases is quite difficult due to steep streambanks, existing buildings, bridge crossings, etc. The obtaining of rights of way for temporary access for construction operations will be the responsibility of the City of Fitchburg as one of the cooperative agreement efforts. These various access points will be over both public and private properties which were in the original 1936 - 1937 project.

In view that ownership of the properties has changed in many instances and the land use has been altered by removal and/or construction of new buildings, contact with the owners will be made to obtain new Rights-of-Entry. This work will be coordinated with the city of Fitchburg by personnel of the New England Division to assure proper liaison and public relations with those involved.

Temporary Construction Easements

Proposed temporary construction easements required in conjunction with the project comprise 22 sites with access thereto. They will be utilized for storage of construction materials and equipment. The 22 sites vary in area from 1,000 to 5,000 square feet. Collectively they comprise about 1.52 acres and will be used for terms varying from one to three months. Based upon preliminary investigations, seven of the sites are currently owned by the city of Fitchburg and 15 are under private ownerships. The necessary easement areas can best be described as those open adjacent lands outboard of the river banks.

Costs

In view that the project does not require any new real estate acquisition and that practically all easements were obtained under the original project, it is anticipated that there will be no real estate costs involved.

Following is a listing of the work sites and names of presently known owners of land over which temporary easements will be required:

Work Site	Owner
A	James River Inc.
B	(Believed to be City)
C	Anwelt Corp. & Independent Lock Co.
D	Richard Manooshian
E	City of Fitchburg
F	Fitchburg Yarn Co., Speedway Gasoline and Independent Cleaners
G	Caravella Realty
H	Caravella Realty
I	City of Fitchburg
J	Nest Fresh Eggs, Inc.
K	City of Fitchburg
L	General Electric Corp. & City of Fitchburg
M	Jennison Company
N	The Hope Company
O	Vermont & Massachusetts Railroad (B&M)
P	" " "
Q	Vermont & Massachusetts Railroad & the Keating Co.
S	Fitchburg Gas & Electric Co.
T	" " " "
U	Simonds Saw Co.
V	City of Fitchburg
W	City of Fitchburg

Q. DEPARTURES FROM AUTHORIZED PLAN

1. Departures - The significant difference between the present Scope of Work and that authorized in the 25 January 1965 Survey Scope Report is as follows:

a. Deletion of excavation of approximately 20,000 cubic yards of silt, sand and gravel between the railroad bridge (Station 493+00+__) below Rollstone Street and the highway crossing at Laurel Street (Station 471+00+__).

b. Removing of remains of existing syphon dam and provide necessary regrading and riprap protection. Approximate location of work is between stream stations 361+00 to 366+00. Refer to work item "V" on General Plan No. 3.

c. Stabilize riverbank in vicinity of Station 577+00 above Oak Hill Road. See Item "B" on General Plan 1.

d. Remove abandoned bridge abutments at Station 430+00 near the Harvard Street Bridge. See Item "T" on General Plan 2.

2. Reasons for Departures

a. Present hydraulic analysis does not support the prior defined removal of 20,000 cubic yards of silt, sand and gravel noted in Paragraph 1a above.

b. Changed conditions of the stream since the 1965 report necessitates providing bank stabilization above Oak Hill Street, and removal of the abandoned bridge abutments near the Harvard Street bridge overpass.

c. The syphon dam was seriously damaged and destroyed by flooding which necessitates regrading of the streambed in the vicinity of the dam. In view of the fact that a former sewer line crossing has been abandoned by the city there is no reason to reconstruct the syphon dam.

3. Miscellaneous - The bank stabilization near Oak Hill Road and removal of bridge abutments near Harvard Street are minor additions. In general, the work relating to the existing crib walls is unchanged.

The estimated construction costs of these work items are:

New Additional Items	
Item 1b	$ 291,000
Item 1c	5,000
Item 1d	10,000
Subtotal	$ 306,000
Deleted Items	
Item 1a	$ -42,000
Estimated Project Cost Increase	$ 264,000

R . CONSTRUCTION PROCEDURES AND DIVERSION PLANS

1. General - The rehabilitation project will require minor temporary type diversions of river flows within the streambed to construct some of the project items. However, no major stream diversion structures or systems are required for accomplishing the work. Further, temporary roads or bridges are not required to be constructed for diverting or handling public traffic purposes.

2. Construction Procedures and Diversion Plans

a. Minor and temporary diversion of stream flows from one side of the riverbed to the other will be required for constructing new concrete walls, grouting of bases of existing walls, etc., at work sites A, B, C, E, F, G, J, K, L, O, P and Q.

b. It does not appear that any stream diversion is required to accomplish work items D, H, I, M, N, R, S and T.

c. All diversion facilities will be removed upon completion, inspection and acceptance of work at each project site.

3. Miscellaneous

a. An existing 45" sewer pipe meanders in, across and along the river through the built-up area of the city down to the East Fitchburg Wastewater Treatment Plant near the Leominster town line. The contractor shall be required to use caution when working in these sewer locations as there is not much protective cover or depth over the sewer.

b. Most waterline crossing over the river are in the utility bays of the bridges and will not present any problems. However, there are a few laid under the streambed and caution will have to be exercised during construction.

c. Traffic control in the built-up areas will be required as well as project coordination with the city of Fitchburg Department of Public Works.

S . ACCESS ROADS

1. General - The project is located in a highly urbanized area and all streets in the vicinity of the site are frequently heavily congested with local city traffic. The overall channel rehabilitation work extends over a 4.4 mile reach of the North Nashua River and physical access to the river is often difficult due to relatively steep riverbank sections, industrial buildings and facilities existing on the riverbanks, various small dams and bridge structures.

Construction and supplier vehicles and equipment will utilize these existing streets supplemented by short sections of temporary work roads to the various project work sites along the river. These short temporary roads are on both city and privately owned lands for which proper temporary real estate easements or permits will have to be obtained. In some locations, especially where long mill type buildings and overly steep banks exist, the existing river bed will provide access for construction operations. In numerous locations it is anticipated that existing public and private drives can be utilized. No major access or haul road system has to be built for the project.

Upon completion of construction the temporary work roads will have to be restored to their original condition where necessary.

2. Traffic Control - In view of the fact that the project work areas are immediately adjacent to existing city streets and built-up areas, it is anticipated that traffic control personnel and signs will be required at various locations for the purposes of expediting the work and extending safety precautions.

T. CORROSION MITIGATION

The rehabilitation project does not contain any operating equipment, steel gates, tracks, etc., nor were there any installed metal features in the original 1937 project except fencing on top of some flood protection walls for safety measures.

The only metal buried or immersed in water on this restoration project is the steel portions of the gabions used for slope protection. The metal will be covered by plastic to protect it from corrosion. No other protective measures are deemed necessary.

U. CONSTRUCTION MATERIALS

1. General - The channel rehabilitation work does not require overly large quantities of construction materials. Some items of work are grading and shaping of areas which do not need materials. The obtaining of construction material for the project does not pose any problems in availability, procurement,or meeting contract completion dates.

2. Availability of Construction Materials

a. On-Site Excavations. Excavations shall in general consist of the removal of deteriorated concrete crib walls including the stone filling, the removal of existing riprap, the removal of large boulders from the streambed, and excavations in artificial man-made fills for channel cut slopes and for placement of concrete structures. This material is not expected to be suitable for layered fill placement or for backfilling behind concrete structures. Selected stone filling salvaged from the removal of the crib walls will be used for filling of gabion cages. Stone removed from the riverbed and riprap removed from areas "F" and "J" that meets rock slope protection gradation and shape factor may be used for the construction of rock slope protection. Part of the riprap removed from areas "F" and "J" may also be used for bedding stone under the rock slope protection.

Except for some selected stone sizes encountered during excavation, it is expected that most of the excavated material will be wasted.

b. Earth and Rock Material Furnished by Contractor.

(1) Earth materials for pervious fills, for backfilling of retaining walls, and for gravel bedding and gravel fills will be furnished by the contractor. Deposits of bank run sand and gravel are available from several active commercial sources within a 5-20 mile radius of the site.

(2) Rock materials for filter stone shall be furnished by the contractor. Rock materials for rock slope protection, bedding stone and for filling of gabion cages will be available in part from salvage of on site excavation and the balance furnished by the contractor from local commercial quarries within a 20 mile haul distance of the site. Filter stone material is avilable from local suppliers of concrete aggregate materials.

c. Concrete. The project will require approximately 2,000 cubic yards of concrete for construction and repair of retaining walls along the banks of the river. The concrete will be subjected to severe climatic conditions with alternate cycles of freezing and thawing during the winter months. Therefore, for durability, air entrained concrete is considered mandatory. The walls will not be subjected to continuous high velocity flows of water and will require only regular quality structural concrete. In view of the quantities of concrete required and the small size of the structures the specifications will provide for a manual type concrete plant with concrete mixed by stationary or truck mixers. The plant shall have a minimum capacity to produce 40 cubic yards of concrete per hour. There are several concrete suppliers within a fifteen mile radius of the project meeting the stated requirements.

d. Cementing Materials - The structures are not exposed to any special conditions requiring special cements, therefore, the use of Type I portland cement will satisfy the requirements for this project. It is not considered economically feasible to use pozzolan or special cements because of the small quantities of concrete required. No special investigations of portland cements have been conducted, as cement used in this area is usually supplied by cement mills from the New York Hudson River Valley, Pennsylvania Lehigh Valley, or Thomaston, Maine areas. Some of these mills do not manufacture Type I cement but do manufacture Type II, therefore Type I or II portland cement will be permitted.

e. Aggregates - There are six previously tested and approved sources of aggregate within a twenty mile radius of the project site. The six sources have been previously reported in Technical Memorandum No. 6-370, "Test Data - Concrete Aggregates in Continental United States," Volume 5 as follows:

Latitude 42°N, Longitude 71°W

1. Holden Trap Rock Co., Holden, Mass. Index No. 2 (revised)
2. Mario Pandolph Co., Sterling, Mass. Index No. 4
3. Trulson Sand and Gravel Company, Holden, Ma. Index No. 5 (revised)
4. P.J. Keating Company, Lunenburg, Mass. Index No. 20 (supplemental)
5. San-Vel Corp. Littleton, Mass. Index No. 22 (supplemental)

Latitude 42°N, Longitude 72°W

6. R.T. Curtis Sand and Gravel Co., Barre, Mass. Index No. 9 (supplemental)

Aggregates from these sources are used in concrete supplied to the project area. Aggregates from these sources have been used in a number of Federal, State and local projects and their service record is considered satisfactory, although it is noted that the period of record is approximately twenty years. The maximum aggregate size required shall be 1-1/2 inches. Because of the limited quantity of concrete needed the required aggregate gradations will conform to the State specifications normally used in the area.

3. Government Furnished Equipment or Materials. The Government will not furnish and/or install any installed equipment or materials for the project. The Government will not furnish any construction type equipment or supplies for the project or upon completion of the project turn over to the city of Fitchburg any operation and maintenance equipment material.

V. ENVIRONMENTAL QUALITY ENHANCEMENT MEASURES

1. General - The rehabilitation project is principally in an existing developed area of the city where commercial and industrial establishments line both sides of the river and in many cases their buildings and structures are right at the edge of the stream. Approximately 25 existing bridges cross the reach of the river within the project site. These bridges are utilized for vehicular traffic, railroads and pedestrian crossings and are of various types of construction and state of repair. Approximately 5 privately owned dams exist within the project site, and are basically used for diverting river waters for industrial use and fire protection in adjacent private manufacturing installations.

As mentioned in the Water Quality section of this memorandum two wastewater treatment plants have been constructed in Fitchburg under provisions of Public Law 92-500, Federal Water Pollution Control Act Amendments of 1972. These plants are now in operation and the water quality of the stream has notably improved, especially esthetically.

In addition to providing flood protection it is intended that the new rehabilitation work will improve the visual aspects of the channel and riverbanks. It is believed that the project will fulfill the desires and intent to provide a harmonious relationship between the stream environment and its functional purpose as a conveyance facility.

2. Architectural Designs - Typical details of the flood protection structures to be built in the project are shown on Plate No. 4.

The concrete floodwalls will in general not be higher than 15 feet above the streambed. Primary esthetic consideration will be made to provide simple mass and exposed surface texture relationships which are commensurate with the functional requirements of the project.

Where existing stone rubble walls can be repaired this will be accomplished utilizing similar stone and rock.

In one location a gabion wall will be constructed for slope protection. These gabions are 3'x3'x12' steel mesh cages filled with natural native stone and placed on top of each other. The visual effect of the natural stone will be in harmony with that section of stream.

The exposed surfaces of new concrete floodwalls will receive a Class B finish (EM 1110-2-200, Change 2, 30 July 1973). In locations where fencing is required on top of floodwalls, colored plastic coated chain link fencing will be utilized for safety purposes and aesthetic enhancement.

3. Landscape Treatment - The project will have as a minimum new topsoiling and grass seeding type of landscape construction. There will not be any large planting of trees or shrubs. However, some new vegetation is necessary to assist in eliminating erosion in critical locations which will also improve the surroundings and river views. In areas where there are existing large trees which may interfere with flood flows these will be removed and in some cases replaced with selected shrubs or small trees.

4. Streambed Improvements - Part of the rehabilitation will include cleanup of debris in the river and removal and relocation of riprap which has become dispersed over the riverbed at many locations.

Shoaling at five locations in the riverbed will be removed so as to provide better stream flow and eliminate places where miscellaneous debris can be lodged.

Selective positioning of boulders will be accomplished to cause ripples in the water and enhance visual effects.

5. Miscellaneous - During the engineering and design stage considerations are being made which will aid the city of Fitchburg in their long range plan to develop a greenbelt and walkway along the banks of the North Nashua River. These considerations will aid in minimizing adverse effects on natural beauty in the various project areas, as specified in ER 1165-2-2 and EM 1110-2-38. Some of the considerations are:

a. Use of stone gabions near Oak Hill Street to lessen visual contrast with existing granite walls on opposite side of the river.

b. To leave some construction access roads, leading down relatively steep banks in place so as to afford a future access point to the river and better future walkway opportunities.

c. Providing a textured surface on exposed new concrete retaining walls which are more readily observed by the public. Surface texturing is an alternative to plain concrete wall. (Class B Finish).

d. Utilizing herbaceous cover, rambling shrubs or vines for revegetation, especially in areas that are not readily accessible for maintenance. Exposed slopes will be stabilized with jute netting or similar mulch in conjunction with planting.

e. Placing shrubs and/or vines above walls to lessen the harsh unnatural form of long walls adjacent to the river.

f. In regard to vegetation and its management along the river, and keeping in mind the functional purpose of the project for flood protection and not allowing interferences with normal and possible flood flows, planting "project guidelines" were suggested. These are also serving as a basis for coordination with local greenbelt advocates. The guidelines are as follows and are shown on the next sketch.

6. Recommended vegetation management guidelines for the river reaches station 580+00 through 440+00 and 400+00 through 345+00 are as follows:

a. Except for specific trees to be identified and preserved for esthetic reasons, all trees 3 inches in diameter or greater will be removed from channel bottom and river banks to an elevation 8 feet above river invert or to top of river bank, whichever is lower.

b. Only vegetation of a small variety and sufficiently flexible to pose a minimum hydraulic restriction would be allowed to remain or be planted in the zone between river invert and 8 feet above. Existing vegetation locally known as Bamboo and Sumac would fall in this latter category.

c. All dead, dying, tipping or otherwise unstable trees greater than 6 inches in diameter in the zone 8 to 15 feet above river invert or to top of river bank, whichever is lower, will be removed.

W. COST ESTIMATES

1. General - The estimated project construction and operation/maintenance costs are based on average bid prices for similar work in the same general area and at a price level of July 1977.

For a detailed breakdown of the construction costs and individual work items involved refer to Attachment B.

It is noted that there are no real estate takings, lands, damages or relocations involved with this project and therefore no real estate costs are shown.

2. Project First Costs - The construction costs include all labor, material, equipment, insurance, mobilization and demobilization and a reasonable amount for contractor overhead and profit to complete the project.

A separate item for construction contingencies in the amount of 25% is carried at this stage of design to account for any unforeseen construction work and the nature of the rehabilitation work.

Separate costs for Engineering, Design (E & D), Supervision and Administration (S & A), are also included. The S & A costs include construction inspection, and supervision and administration costs on engineering and design during construction.

Since the project construction period is less than two years no cost for interest during construction is included.

The total First Cost of the project which includes the above mentioned items is estimated at $2,100,000. A summary of the First Costs is shown in the following table:

TABLE I

Project Features	Estimated Cost
Lands and Damages	--
Relocations	--
Construction of Project Work Items	$1,320,000
Sub Total	$1,320,000
Construction Contingencies (25%)	330,000
Sub Total	$1,650,000
Engineering and Design (E & D)	$ 280,000
Supervision and Administration (S & A)	$ 170,000
Total Estimated First Costs	$2,100,000

3. Annual Charges - The annual amortization and interest amounts are based on the total estimate for First Costs and an interest rate of 3-1/4 percent amortized over the 50 year assumed economic life of the project. The 3-1/4% interest rate is utilized in the project economics for the following reasons:

a. The original project was authorized by the Congress in 1936 and construction was completed by the Corps of Engineers in 1937. The proposed channel rehabilitation project does not require any new lands, damages or relocations. The rehabilitation work will be accomplished within the real estate limits acquired for the original 1936 project. New updated assurances are required from the city of Fitchburg.

b. The 3-1/4% interest rate used in the economic analysis has been the subject of considerable discussion. Accordingly, an explanation of the derivation of this rate is appropriate. The interest rate is in accordance with a Water Resources Council (WRC) regulation implemented in December 1968. This regulation revised the method of computing the interest rate as previously outlined in Senate Document 97 of 29 May 1962. The regulation permitted an exception, however, for those projects already authorized such as the channelization restoration which was authorized in 1966. The exception noted that if an appropriate non-Federal agency provided - prior to 31 December 1969 - satisfactory assurances that requirements of local cooperation associated with the project would be met, then the previous interest rate would be retained. Local cooperation and assurances were obtained from the city of Fitchburg in 1936-1937 for the original flood protection project and they are considered still valid for this proposed restoration work. As a result, the interest rate was retained at 3-1/4%.

It is noted that in Section X - Project Economic Analysis, a sensitivity analysis of the project at 6-5/8% is presented which is the effective rate commencing on 1 October 1977 for Federal water resource projects.

Allowances are made for annual operation and maintenance costs in the amount of $5400 per year. A breakdown of the costs is shown in this Section. The project does not require any operations type work because there is no installed equipment or operating structures. The maintenance work involves caring for vegetation, debris removal, riprap repairs and cleaning the streambed.

TABLE II

Channel Rehabilitation - North Nashua River
Fitchburg, Massachusetts

Estimated Annual Operation and Maintenance Costs

a. Normal maintenance will consist of vegetation control on rock slopes, removing debris from channel, and inspection of facilities.

1. Vegetation Control on Rock Slopes

320 hrs. @5.00/hr.	$1,600.00
Materials and Supplies	250.00
	$1,850.00

2. Removing Debris From Channel:

160 hrs. @ $5.00/hr.	$ 800.00
Truck and Driver - 80 hrs. @ $8.00/hr	640.00
	$1,440.00

3. Inspection of Facilities, Four Times Annually

4 hrs. per Inspection X4 = 16 Man Hours	
16 hrs. @ $5.00/hr.	$ 80.00
Total Maintenance	$3,370.00

b. Miscellaneous:

1. Concrete Maintenance, Cleanup and Minor Repairs $ 500.00

2. Replacement of Riprap

50 CY @ $25.00/CY	$1,250.00
Crane Rental for 1 Day	280.00
Total Miscellaneous	$2,030.00

c. Recapitulation:

Maintenance	$3,370.00
Miscellaneous	2,030.00
TOTAL	$5,400.00

Since the project does not have any operating facilities or equipment such as movable gates, turbines, lock devices, etc., there are no costs included for major replacements.

A summary of the Annual Charges is as follows:

TABLE III

Item	Estimated Annual Cost
Interest and Amortization (3-1/4%)	$ 85,533
Operation and Maintenance	5,400
Major Replacements	0
Total Annual Charges	$ 90,933
Adopt	$ 91,000

4. Cost Apportionment - All First Costs of the project in the amount of $2,100,000 will be borne by the Federal Government. Local interests are not responsible for any portion of the First Costs.

The Annual Costs for operation and maintenance of the project which are estimated at $5,400 per year, are the local responsibility of the city of Fitchburg, Massachusetts.

5. Comparison of Estimates - The current First Cost Estimate of the project is $2,100,000. The following table presents a history of the project costs since the Survey Scope Report for the project was prepared in January 1965.

TABLE IV

Comparison of Cost Estimates

Project Feature	(Survey Scope-1965) Project Document	PB-3 (1976)	(1 Aug 1977) Current
Total Est. First Costs	$ 700,000	$1,950,000	$2,100,000
Total Federal Cost	700,000	1,950,000	2,100,000
Total Local Cost	0	0	0

X. PROJECT ECONOMIC ANALYSIS

1. Extent and Character of the Flood Area - Over 800 acres of land in the city of Fitchburg are located in the floodplain. This area is completely built over from the headwaters of the North Nashua River in the upper part of the city to just north of the Fitchburg-Leominster Airport in the lower part of the city. Occupants of the floodplain include 65 industrial plants, 150 commercial establishments, over 120 dwelling units of various types, a public utility, railroad lines and roadways. The land use and trend of development in the lower part of the city is toward commercial, light and clean industry with some intermixed residential areas.

2. Damage Surveys - A detailed damage survey was conducted by damage analysts of the NED in 1976. This survey consisted of a property by property canvas of all structures in the floodplain as defined by the highwater lines of the record flood and all adjacent properties up to elevations of three feet above the record flood level. The damage analysts made their own assessment of potential flood losses and verified them with knowledgeable property owners when possible.

The damage survey evaluated physical damages to structures and their contents, as well as nonphysical losses such as loss of business and wages, and the emergency costs associated with a flood, including the costs of temporary shelter and subsistence. Estimates were made starting at the stage at which damages would begin and continued at one foot intervals until the record flood plus three feet elevation was reached. All prices were updated to 1 August 1977 levels. Stage damage curves are shown on Attachment E.

3. Recurring and Annual Losses - Losses by stages referenced to the record flood level were tabulated for the flood area as delineated by hydrologists. Recurring losses are estimated at $28.5 million in the event of a flood with the 1936 cfs under 1976 conditions. If the floodwaters reached the height experienced in 1936 losses would amount to $43.5 million. These losses would be concentrated in industrial and commercial areas. The following breakdown of damages was calculated based on the floodwaters reaching 1936 levels.

	Losses as a Percentage of Total Losses
Industrial	83.88
Commercial	9.44
Public	2.28
Utility	2.22
Residential	1.08
Highway	1.05
Railroad	.06

NOTE: Figures do not add to 100.00 due to rounding.

Recurring losses were combined with stage-frequency data to derive average annual losses. All prices are as of August 1, 1977.

The estimated average annual losses amount to $3.5 million.

4. Benefits

a. Flood Damage Prevention Benefits - Tangible flood damage benefits are determined by the following method: The difference is taken between annual losses under the without-project conditions based on continuance of existing deterioration condition and residual annual losses to be anticipated with the proposed project. In this case, such benefits amount to $415,000 at 3-1/4%. For information purposes these would be $389,000 at 6-5/8% interest rate.

Significant intangible benefits would also result from the proposed project. These would include a reduction in health hazards caused by polluted floodwaters, a potential improvement of the social and economic well-being of both residents and economic activities in the area, and a cutback in the demand for municipal services (police, fire, public works departments) during flood emergencies.

b. Area Redevelopment Benefits - In labor market areas which have been designated as Redevelopment Areas, Senate Document No. 97 of the 87th Congress directs that the project benefits shall be considered to be increased by the value of the labor and other resources required for the project construction and expected to be used in project operation, project maintenance, and additional area employment during the life of the project. Otherwise, such labor and resources would not be utilized or underutilized.

Fitchburg lies in the Fitchburg-Leominster SMSA which has been designated a Title IV Redevelopment area under PL 89-136 by the Economic Development Administration. The unadjusted unemployment rate was 6.7% in June 1977 and 10.7% in June 1976.

The records of this office indicate that in the average civil works project, the labor cost approximates 27 percent of total construction costs. The construction cost of the project is currently estimated at $1,650,000. Labors share amounts to $445,500.

However, it is regular practice for a contractor to maintain a skilled skeleton crew and fill the rest of his requirements from the local labor pool. It is estimated that 75 percent of the laborers will be locally hired for this project. While not all of this labor will come from the rolls of the unemployed, the jobs that they will leave will be filled by either the unemployed or the underemployed; thus, 75 percent is the figure used. It is estimated that the work will take 18 months to complete.

At a discount rate of 3-1/4%, the derivation of this facet of the annual redevelopment benefit is as follows:

$1,650,000	X	0.27	=	$ 445,500	Total Labor Cost
445,500	X	0.75	=	334,125	Local Labor
167,063	X	0.969	=	161,804	Year 1
167,063	X	0.938	=	156,711	Year 2
				$ 318,515	PW

$318,515 X .04073 (CRF 50 yrs @ 3-1/4%) = $12,973

No benefit is considered for labor engaged in maintenance and operation of the project after construction; the need is small ($5400/year) and the work will be handled by the regular public work force of the community.

The area redevelopment benefit is $13,000 @ 3-1/4%. For information purposes this benefit would be $21,000 @ 6-5/8% interest rate.

c. Future Benefits - Additional benefits will accrue to the project as it affects future growth in three categories: inundation reduction, intensification, and location. They are differentiated as follows:

(1) The future inundation reduction benefit is the value of reducing flood losses to activities which will use the floodplain in the future without a plan. The benefit consists of the reduction of the amount of future damages plus related costs (example: floodproofing). Future damages are discounted to the base year of the project.

(2) The intensification benefit accrues to commercial, industrial, and agricultural sectors. The benefit is the value of a plan to activities which, with protection, are enabled to utilize their property more intensively.

(3) The location benefit is the value of making floodplain land available for new use by reducing flood hazards to activities that would use the floodplain only with protection.

d. Benefits - The area along the North Nashua River in Fitchburg is highly developed and few parcels of land are available for construction. A discussion with the town planner revealed no imminent plans for either changes in current land usage or urban renewal in the floodplain.

e. Summary of Benefits - Evaluated flood damage prevention and area redevelopment benefits are summarized below.

Summary of Estimated Annual Benefits

Type	Annual Benefits 3-1/4%	6-5/8%
Flood Damage Prevention	$415,000	$389,000
Area Redevelopment	13,000	21,000
Total	$428,000	$410,000

5. Estimated Annual Costs - The estimated annual costs for the project for determining the Benefit Cost Ratio consists of amortization, interest payments and operation and maintenance. Since the project does not involve operating equipment such as locks,dams, powerhouse, etc., the costs are primarily of a maintenance nature to remove debris, maintain riprap and walls, and cut vegetative growth which may hinder stream flow. A summary of the estimated annual costs for the project based on the authorized 3-1/4% and the projected 6-5/8% interest rate to be used on water resource projects effective 1 October 1977 is as follows:

Estimated Annual Costs

Item	Interest Rate 3-1/4%	6-5/8%
Amortization of Interest*	$ 85,533	$ 144,984
Operation and Maintenance	5,400	5,500
Major Replacements	--	--
Totals	$ 90,933	$ 150,484
Adopt	$ 91,000	$ 150,500

*Based on $2,100,000 estimated cost and a 50 year project life.
3-1/4% CFR = .04073
6-5/8% CFR = .06904

6. Benefit Cost Ratio (BCR) - Based on the above annual benefits and costs the present Benefit Cost Ratio for the project is as follows:

Benefit Cost Ratio (BCR)

Interest Rate	Annual Benefits	Annual Costs	BCR
3-1/4%	$ 428,000	$ 91,000	4.7 to 1.0
6-5/8%	$ 410,000	$ 150,500	2.7 to 1.0

7. Summary - The Benefit Cost Ratio for the project at either the authorized or current monetary interest rate indicates that the project is still economically feasible and worthy of immediate implementation.

Y. LOCAL COOPERATION

1. General - In accordance with Section 3 of the 1936 Flood Control Act, as amended, local interests will be required to provide the necessary items of local cooperation as outlined in the Project Document and included in the Section of this report entitled "Project Authorization".

2. Local Assurances - A request for formal assurances from the Commonwealth of Massachusetts on behalf of the city of Fitchburg will be made following approval of this report and prior to the initiation of construction of the channel rehabilitation project, which is tentatively scheduled for the fall of 1978. Construction of the proposed restoration project will require non-Federal interests furnish assurances imposed by the authorizing document and current additional requirements satisfactory to the Secretary of the Army. These items of local cooperation include the following:

a. Provide without cost to the United States all lands, easements, rights-of-way, utility relocations and alterations, and highway or highway bridge construction and alterations necessary for project construction.

b. Hold and save the United States free from damages due to the construction, operation, and maintenance of the project except where such damages are due to the fault of the United States or its contractors.

c. Maintain and operate the project after completion without cost to the United States in accordance with regulations prescribed by the Secretary of the Army.

d. Prevent future encroachment which might interfere with proper functioning of the project for flood control.

3. Views of Local Interests - The channel rehabilitation project has been presented to the public through a public involvement program and two attachments to this report present the local views. The attachments are:

a. Letter dated 13 September 1976 from the Honorable Michael S. Dukakis, Governor of Massachusetts which in essence states that he endorses the Environmental Quality (EQ) plan for overall flood control planning in the North Nashua River Basin. The channel restoration project is one of the individual projects contained in the plan.

b. Resolution passed by the Fitchburg City Council in formal session on 15 December 1976 in which the council favored the channelization project.

4. Non-Federal Costs - Since there are no costs involved for lands, damages, or relocations, no non-Federal costs are involved for these items.

Upon completion of the channel restoration project the non-Federal interests (city of Fitchburg, Massachusetts) will operate and maintain the project at an annual cost currently estimated at $5400. Local interests are willing and capable to meet the operation and maintenance requirements and costs on non-Federal participation.

5. Miscellaneous - In acquiring lands, easements and rights-of-way for construction of the project, the city will comply with the applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, approved 2 January 1971.

AA. SCHEDULE FOR DESIGN AND IMPLEMENTATION

1. Design - Upon approval of this document it is anticipated that preparation of contract plans and specifications will be initiated in the fall of 1977 and completed in the winter of 1977. Design will be accomplished during FY1978.

2. Construction - Based on the availability and authorization of construction funds in the FY1979 program it is expected that a construction contract award will be made in the early part of FY1979 and all work completed within 1-1/2 years.

A 1-1/2 year construction period is considered adequate for completion of the project. The project involves work at approximately 23 specific locations in the 3.75 miles of river reach. The majority of work will be accomplished during June through September of the construction year in order to take advantage of that period of time when riverflows are normally low.

AB OPERATION AND MAINTENANCE

1. General - Upon completion and acceptance of the channel rehabilitation project, the city of Fitchburg will be responsible for its complete operation and maintenance for flood control purposes.

2. Operations - As such the project does not have any dams, locks, gates, overflows, contols, mechanical, electric, or power equipment which requires any type of operation. In view of this there is a negligible need for operating personnel, equipment and their support.

3. Maintenance - Periodic inspections will be made of the channel, existing bridge abutments and structures and the constructed local flood protection works by the city of Fitchburg to report conditions and serve as a basis for maintenance work to preserve the works.

All maintenance on the channel and the flood protection improvements will be the responsibility of the city of Fitchburg.

4. Annual O and M Costs - The estimated annual cost of operation and maintenance is $5,400 which will be borne and administered by the city or Fitchburg.

AC RECREATIONAL RESOURCE

The purpose of the channel rehabilitation is for flood control protection and the only project benefits are based on this premise and the authorization. However, the project does offer and increases the future recreational potential of the river area for the inhabitants of the city of Fitchburg.

The new improvements will offer streambank stabilization and protection along numerous stretches of the river. The works will permit future construction by others of pedestrian walkways, bike trails, and picnic areas along the stream. The Conservation Commission for the city of Fitchburg was formed for the purpose of the development of a "greenbelt" along the river within the city limits. That organization has been most active in developing interest in improving the esthetics and recreation along the river.

The Corps with its authorization of the channel project is limited to flood protection works and providing recreational improvements is not included. In various meetings with the Conservation Commission, the Corps has noted this limitation and has offered to assist and act as a liaison with other agencies who have supportive programs in this area. The Bureau of Outdoor Recreation has several matching fund grants for recreation and development, including use of the Land and Water Conservation Fund. The Commonwealth of Massachusetts also has a matching fund program for recreational development in urban areas. Corps assistance, if recreation was authorized, would require a 50-50 cost sharing formula with local interests, which is essentially the least attractive alternative. In view of this reason, the Corps has assumed the role of initiating liaison with other Federal and State agencies for furnishing assistance to the Commission.

It is our present understanding that the city of Fitchburg Planning Coordinator is taking steps to advise the city and Conservation Commission of the more appropriate and applicable supportive programs from other Federal and State agencies to meet their needs.

AD WATER QUALITY

1. General - The waters entering the North Nashua River from tributaries are generally of good quality. However, in the past serious water pollution problems in the main stream have occurred principally from industrial wastes being discharged into the river. The city has numerous paper manufacturing firms which contributed to this problem which was critical prior to and during the preparation of the 1965 Survey Scope Report and on into the mid 1970's. The river in the vicinity of the project had an extremely low water quality rating and was highly colored, turbid, odorous and obnoxious.

2. Wastewater Treatment Facilities - This pollution problem has changed drastically through the cooperative efforts of local, State and Federal Government, private industry and interested individuals and organizations. Considerable funds on water pollution abatement studies and construction of treatment facilities have been expended and within the last year or so two sewage treatment plants have been constructed and placed in operation which are beginning to produce improved water quality conditions in the river, particularly from an esthetic point of view.

The approximate total construction cost for the east and west sewage treatment plants was $30,000,000.

The new West Fitchburg Wastewater Treatment Plant (designed for 15 MGD) has activated carbon facilities in addition to the secondary treatment plant. This plant discharges the treated effluent into the river and is located slightly upstream from the channel project. The plant will treat principally the paper mill wastes in Fitchburg but will also handle the municipal wastes from parts of Fitchburg and the adjacent towns of Ashburnham and Westminster.

The new East Fitchburg Wastewater Treatment Plant was designed for a 14 MGD capacity, provides secondary type treatment only and discharges its effluent into the river just downstream from the channel improvement project. This plant will serve the needs of the town of Lunenburg as well as most of the city of Fitchburg.

These two wastewater treatment facilities were constructed under the provisions of the Federal Water Pollution Control Act Amendments of 1972. The Corps of Engineers, New England Division was part of the joint study Nashua River Program team which developed a total wastewater management program for the entire Nashua River Basin. The principal participants in the study and implementation program were the New England Interstate Water Pollution Control Commission, Commonwealth of Massachusetts Division of Water Pollution Control, State of New Hampshire Water Supply and Pollution Control Commission, and the U.S. Environmental Protection Agency.

3. Minimum Low Flows - Extensive low flow studies for the North Nashua River have been made in connection with the Corps proposed upstream reservoirs at the Phillips, Nookagee and Whitmanville sites. Minimum flows through Fitchburg and the region are desired to secure sufficient supply for industry, recreation, esthetics and streambank wildlife. Water quality studies conducted by the Federal Water Quality Administration in 1968 determined that a desirable minimum flow to maintain water quality on the North Nashua River would be 60 cubic feet per second (cfs) at the Leominster gaging station. This station is below the river reach of the channel rehabilitation work. Subsequently, by correspondence dated 25 February 1975, the U.S. Environmental Protection Agency revised the desired low flow amounts at the Leominster station to the following values:

Minimum Low Flow	Month of Year
43 cfs	May and October
46 cfs	June and September
52 cfs	July and August

4. Conclusions - The present condition of the river is "U" - unsatisfactory. The Commonwealth of Massachusetts has given the river a future classification of "C" - Acceptable for recreational boating, fishing and industrial water supply with or without treatment, depending on individual requirements. Now that the new wastewater treatment facilities are in operation this classification should be attained very soon.

It is considered that the channel rehabilitation project will not adversely affect the water quality of the stream but will improve it by allowing better flow and minimize obstructions which can collect debris, etc.

NOTE: More detailed discussion of both stream water quality conditions and minimum low flow requirements are contained in New England Division Memorandum dated 21 November 1973, entitled "Justification for Altering Project Purposes - Whitmanville Lake, Whitman River - Nookagee Lake, Phillips Brook, North Nashua River Basin," and Appendix E, "Thermal Simulation Analysis," Design Memorandum No. 2 for Nookagee Lake, Massachusetts

AE STATEMENT OF FINDINGS

I have reviewed and evaluated, in light of the overall public interest, the documents concerning the proposed action, as well as the stated views of other interested agencies and the concerned public, relative to the recommended flood protection project (Channel Rehabilitation and Restoration) along the North Nashua River in the city of Fitchburg, Massachusetts.

The possible consequences of this project have been studied according to environmental, social well-being, and economic effects, including regional and national development and engineering feasibility.

1. Environmental Considerations - From an environmental standpoint, the recommended project plan will afford more enhancement than adverse effects. The recommended project will improve the water quality of the North Nashua River by reducing the amount of eroded material entering the river. The esthetics of the area will be enhanced by the improved water quality of the river. The esthetics will also be improved in the project area by displacing an unsightly and undesirable existing physical condition with neatness and control and order offered by the project. The project offers some limited opportunity to benefit fish and wildlife resources by aiding in the improvement of river water quality, riverbed quality, and riverbank wildlife habitat, through selective revegetation. There will, however, be two temporary adverse effects connected with the project. Increased siltation and temporary turbidity is expected during construction, but measures will be taken to hold these effects to a minimum. In addition, some vegetation will be destroyed in the area of the channel improvement and this condition will prevail until revegetation is accomplished.

2. Social Well-Being Considerations - The overriding social well-being consideration in the project area is the reduction of the flood hazard that has caused tremendous damages and human suffering and has restricted normal development over the past four decades. The recommended project will provide a high degree of protection resulting in greater community cohesion and ensuring availability of public facilities during times of flooding. Construction of the recommended project will make possible higher utilization of the area for the planned greenbelt programs which will improve the physical and social environment of not only the project site, but the entire city of Fitchburg. The project will be an asset in protecting the numerous commercial and manufacturing facilities along the river and assure continual employment in plants which could be affected by flooding. There will be no displacement of residential or commercial properties required for construction of the project.

3. Engineering Considerations - From an engineering standpoint the recommended project would provide the highest degree of flood protection feasible because of the highly urbanized nature of the project area. Various nonstructural alternatives were reviewed; however, the channel rehabilitation project was determined to afford the most protection to life and property and be the most feasible.

4. Economic Considerations - From an economic standpoint, the recommended project is an economically optimum plan which provides a high degree of flood protection and enhancement of social well-being and economic growth. The recommended project will have a net effect of increasing employment, tax revenues, and property values and will stimulate growth in the project area.

The project has been presented to the public through Corps of Engineers Public Meetings, working conferences with local and State officials, and distribution of mail material. The project has been endorsed by local and State officials and various conservation groups.

I find that the proposed action, as developed in the Project Design is based on thorough analysis and evaluation of various practicable alternative courses of action for achieving the stated objectives; that wherever adverse effects are found to be involved they cannot be avoided by following reasonable alternative courses of action which would achieve the Congressionally specified purposes; that where the proposed action has an adverse effect, this effect is either ameliorated or substantially outweighed by other considerations of national policy; that the recommended action is consonant with national policy, statutes, and administrative directives; and that on balance the total public interest should best be served by the implementation of the recommendations.

JOHN P. CHANDLER
Colonel, Corps of Engineers
Division Engineer

AF ENVIRONMENTAL ASSESSMENT

An Environmental Assessment, Appendix II, has been prepared for the project in lieu of an Environmental Impact Statement. The project is considered a minor action type of project primarily because of its rehabilitation and restoration aspects. The reasons for using an assessment are provided in the Appendix.

Other attached documents relating to environmental and social-economic issues contained in this Design Memorandum are:

Appendix III - Social and Economic Effects Assessment

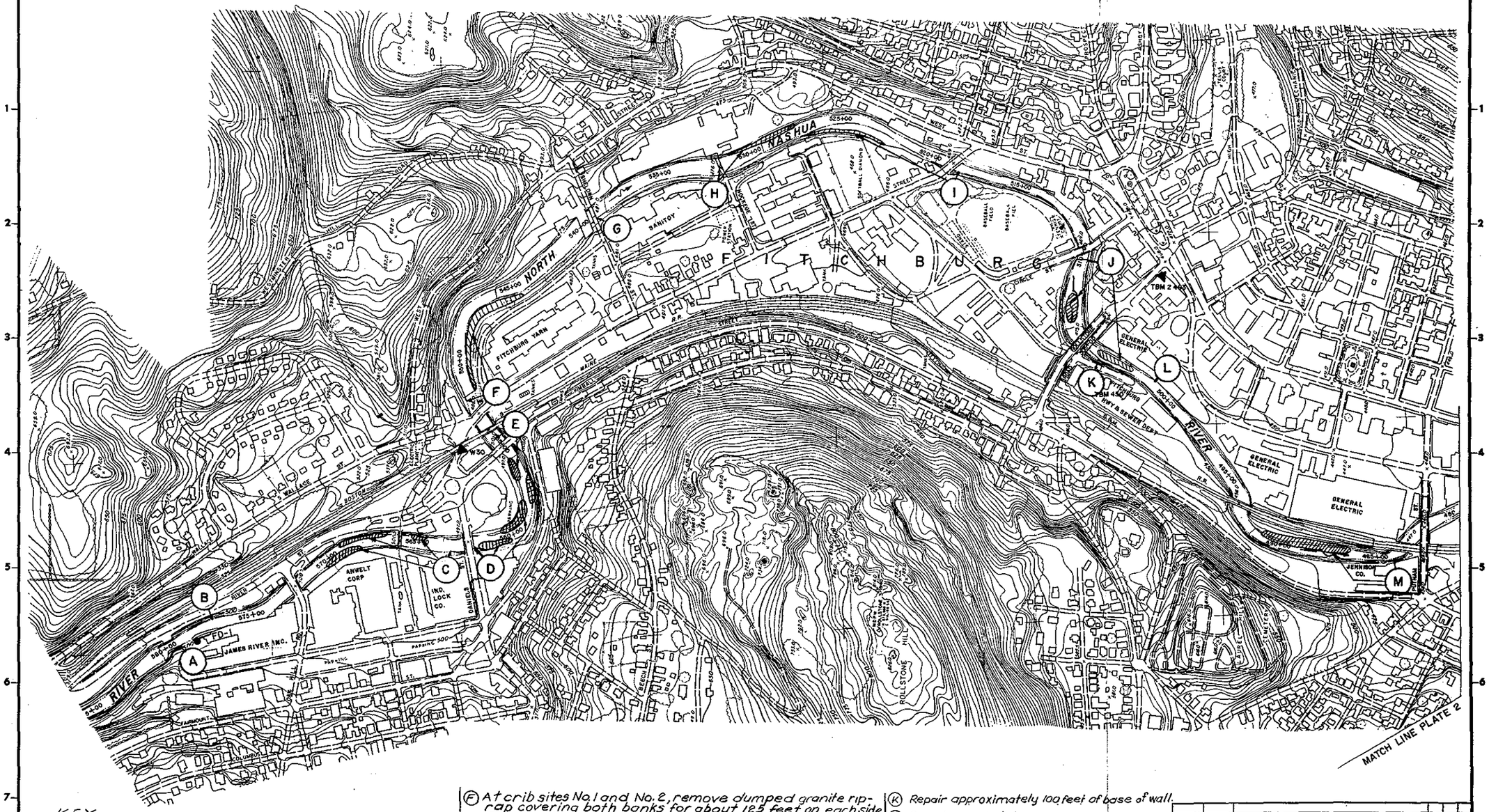
Attachment C - Section 404 Evaluation Report

AG RECOMMENDATIONS

It is recommended that the authorized plan of improvement of channel rehabilitation for flood protection at North Nashua River, Fitchburg, Massachusetts, as outlined in Senate Document No. 113, 89th Congress, 2nd Session, and authorized under Title II, Section 203 of the 1966 Flood Control Act and modified in this report, serve as the basis for preparation of more detailed designs and preparation of contract plans and specifications.

PLATES

CORPS OF ENGINEERS — U. S. ARMY



KEY

(A) Place 36" rock slope protection for about 220 feet and remove random boulders in same region.

(B) Remove loose stone wall above El. 495 and rebuild cut stone wall in adjacent location.

(C) Re-grout cut stone wall on right bank for a distance of about 100 feet. Remove shoaling

(D) Repair localized erosion downstream of bridge right abutment and remove broken stone boulders immediately downstream of bridge. Remove shoaling.

(E) Between Kimball Street bridge and B&MRR. bridge, repair channel bottom by grouting cutstones for area of approximately 30 square yards. Remove shoaling.

(F) At crib sites No. 1 and No. 2, remove dumped granite rip-rap covering both banks for about 125 feet on each side. Remove old deteriorated concrete cribbing beneath the dumped granite. Replace right bank with concrete wall and ramp and left bank with concrete retaining wall and backfill. Remove selectively and reposition the large stones in the channel. Shoaling is to be removed.

(G) Repair downstream wingwall south side at Shelden Street bridge. Also repair grouted rip-rap in river bottom and well graded rip-rap is to be placed downstream to prevent further unravelling.

(H) Remove some large stones and replace with well graded rip-rap and reposition existing stone. Shoaling is to be removed.

(I) At 12" utility crossing reset large stone creating a uniform face then imbed well graded rip-rap around large stone. Shoaling is to be removed.

(J) Remove as necessary the existing granite rip-rap to provide a 3' layer of new large size stone; cover over concrete crib site No. 3. Reposition stones in river. Shoaling is to be removed.

(K) Repair approximately 100 feet of base of wall.

(L) Repair grouted rip-rap

(M) Repair existing concrete crib No. 4 by the addition of a concrete cap and resurfacing of several eroded stretcher members. Remove shoaling

GRAPHIC SCALES

1" = 200' 200' 0 200' 400'

LEGEND

SS SEISMIC SURVEY

FD-1 BORING LOG

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

SUBMITTED
CHIEF, SECTION
APPROVAL RECOMMENDED
CHIEF, TECH. ENG. BRANCH
REVIEWED
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF, BRANCH

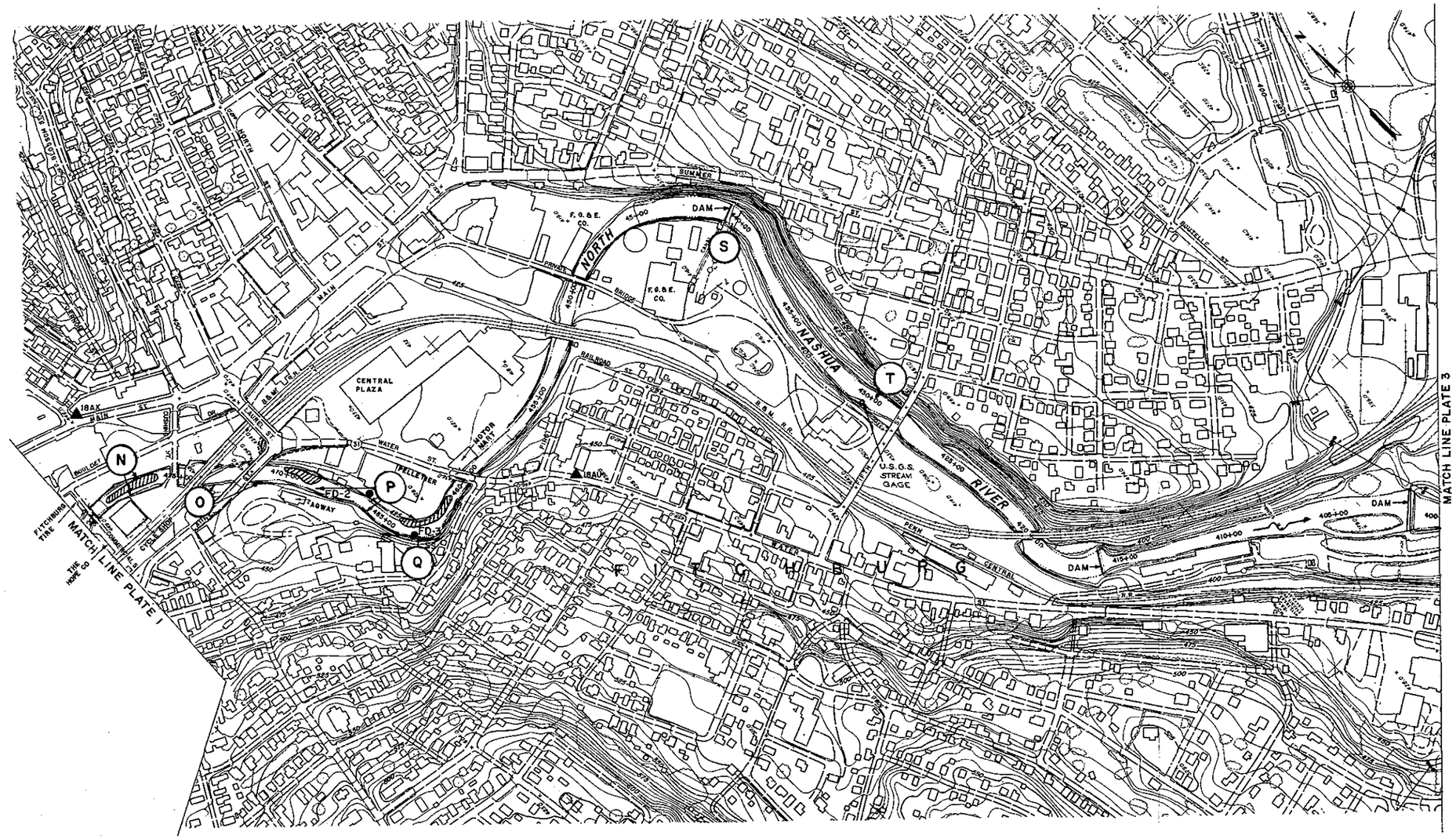
WATER RESOURCES DEVELOPMENT PROJECT
FITCHBURG, MASSACHUSETTS
NORTH NASHUA RIVER
CHANNEL REHABILITATION
GENERAL PLAN NO. 1
NORTH NASHUA RIVER MASSACHUSETTS

APPROVED DATE
CHIEF, ENGINEERING DIVISION

SCALE | SPEC. NO.
DRAWING NUMBER
MER-34
SHEET

PLATE 1

CORPS OF ENGINEERS — U. S. ARMY



KEY

(N) Cap concrete wall on right bank so that its top elevations will be the same as the top elevations along left bank wall. Remove shoaling.

(O) Remove about 250 feet of concrete cribbing at crib Sites No. 5 and No. 6 and replace with concrete walls.

(P) On the left bank, restore approximately 110 feet of wall; remove temporary sand dike and material along base of wall in stream bed. Remove boulders 300' downstream from Laurel St. Bridge. Sandblast wall 310' long - 13' High, and paint fence. Remove rubbish from South bank. Remove shoaling.

(Q) At crib site No. 7, face cribbing with a 1.5 foot thick concrete veneer for a length of 250 feet.

(R) Deleted.

(S) Reset approximately 50 pieces of broken stone boulders downstream of power service dam.

(T) Remove two mid-stream piers (prior removed foot bridge) immediately upstream of the Fifth Street bridge. Abutment in left bank to be retained but upper two courses of granite block to be re-grouted for safety.

GRAPHIC SCALES
1" = 200' 200' 0 200' 400'

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

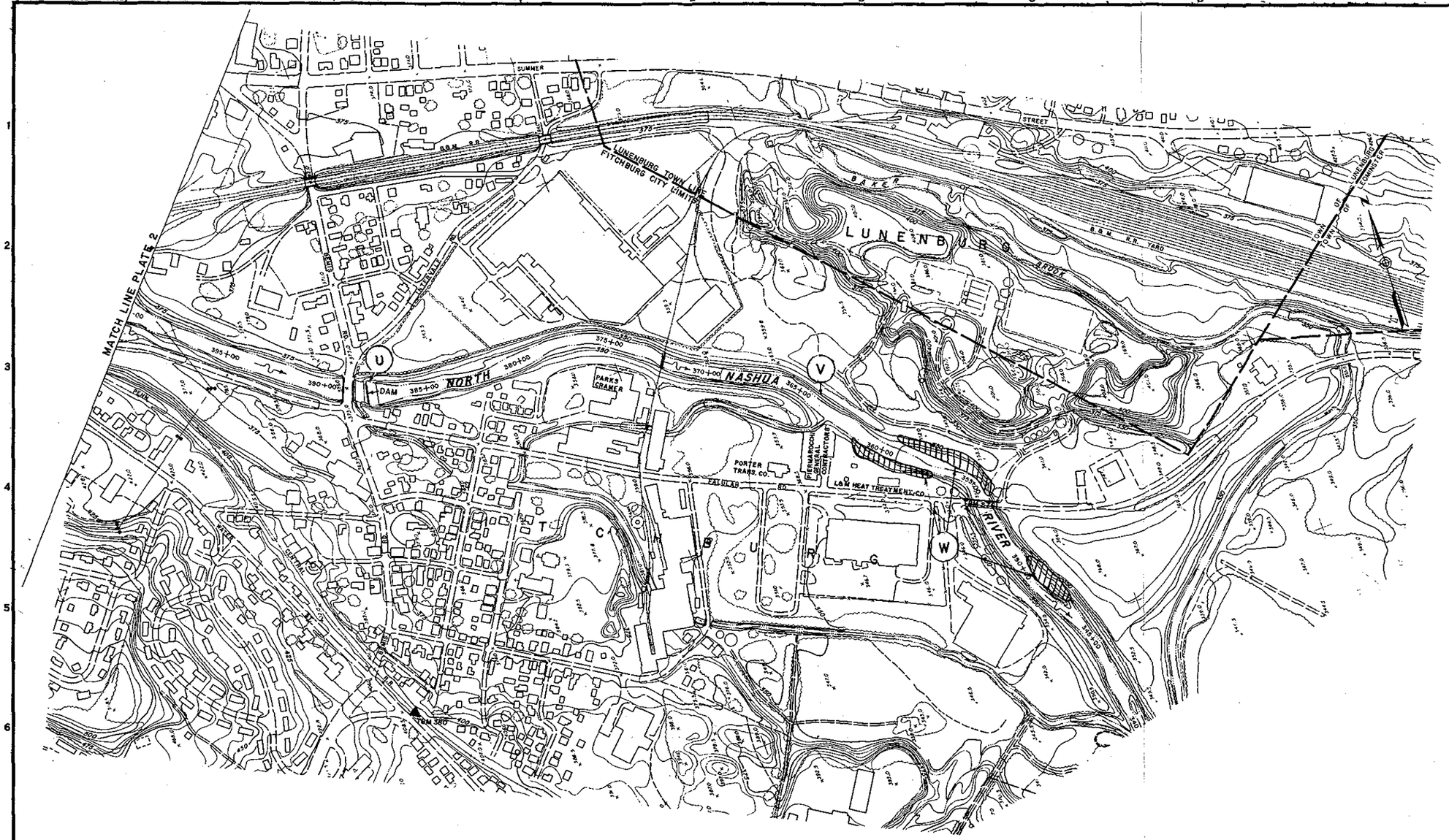
SUBMITTED
CHIEF, SECTION
APPROVAL RECOMMENDED
CHIEF, TECH. ENG. BRANCH
REVIEWED
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF, BRANCH

WATER RESOURCES DEVELOPMENT PROJECT
FITCHBURG, MASSACHUSETTS
NORTH NASHUA RIVER
CHANNEL REHABILITATION
GENERAL PLAN NO. 2
NORTH NASHUA RIVER MASSACHUSETTS
APPROVED DATE
CHIEF, ENGINEERING DIVISION

SCALE | SPEC. NO.
DRAWING NUMBER
MER-34
SHEET

PLATE 2

CORPS OF ENGINEERS, U.S. ARMY



KEY

(U) Reset large broken stones in stream immediately down stream from Bemis Road dam.

(V) Restore and prevent further erosion of banks and river bottom regrade and place rip-rap protection on the adjacent river bank area and restore the outlet of the canal into the river.

(W) Remove shoaling.

GRAPHIC SCALES

1" = 200' 200' 0 200' 400'

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

SUBMITTED:

CHIEF, SECTION

APPROVAL RECOMMENDED:

CHIEF, TECH. DIV. BRANCH

REVIEWED:

PROJECT ENGINEER

APPROVAL RECOMMENDED:

WATER RESOURCES DEVELOPMENT PROJECT
FITCHBURG, MASSACHUSETTS
NORTH NASHUA RIVER
CHANNEL REHABILITATION
GENERAL PLAN NO. 3

NORTH NASHUA RIVER MASSACHUSETTS

APPROVED: DATE:

CHIEF OF ENGINEERS

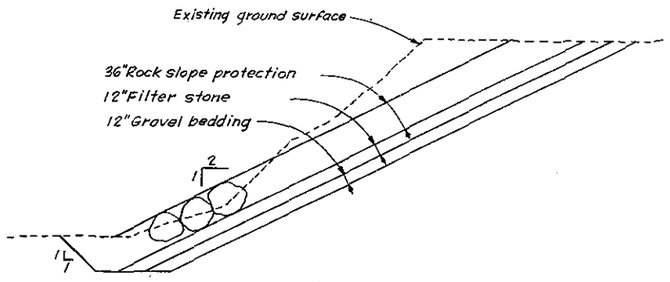
SCALES AS SHOWN | SPEC. NO. | DRAWING NUMBER

MER-34

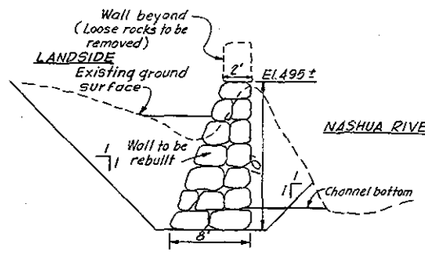
SHEET

PLATE 3

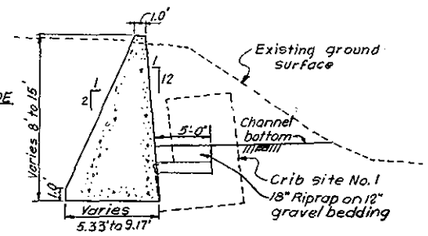
CORPS OF ENGINEERS — U. S. ARMY



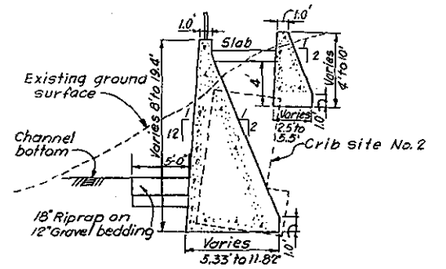
TYPICAL SECTION AT AREA (A)
SCALE: 1"=5'



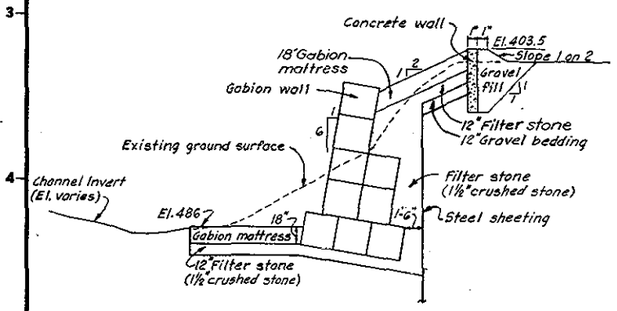
TYPICAL SECTION AT AREA (B)
SCALE: 1"=4'



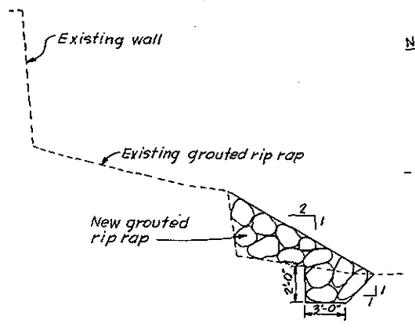
TYPICAL SECTION AT CRIB SITE NO.1 AREA (F)
SCALE: 1"=5'



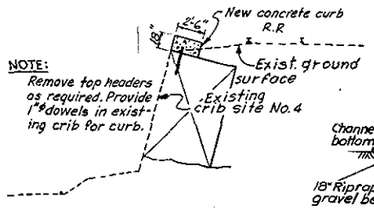
TYPICAL SECTION AT CRIB SITE NO.2 AREA (F)
SCALE: 1"=5'



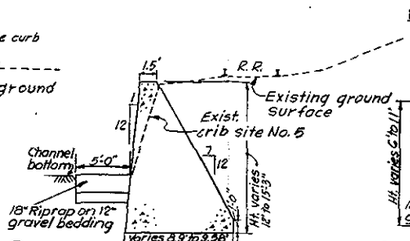
SECTION AT GABIONS AREA (A)
SCALE HOR. 1"=5' VERT. 1"=5'



TYPICAL SECTION AT AREA (L)
SCALE: 1"=4'

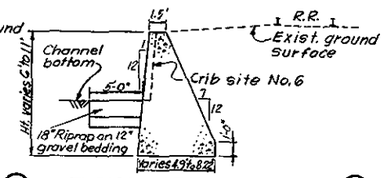


TYPICAL SECTION AT AREA (M)
SCALE: 1"=5'

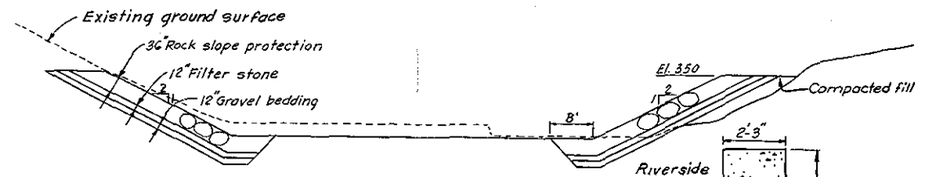


TYPICAL SECTION AT AREA (O)
SCALE: 1"=5'

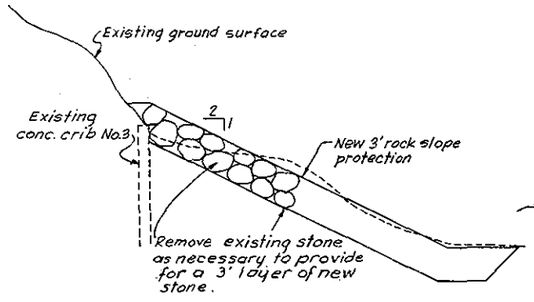
NOTE:
Existing railroad spurtrack to be removed and relayed, as necessary, for removal of existing crib wall and construction of new concrete wall.



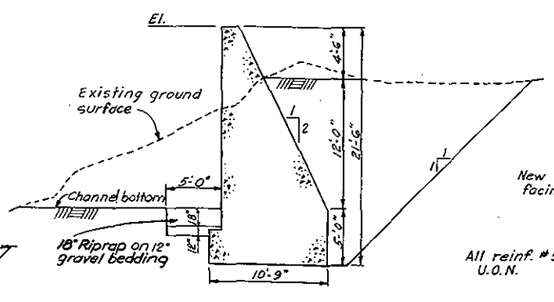
TYPICAL SECTION AT AREA (O)
SCALE: 1"=5'



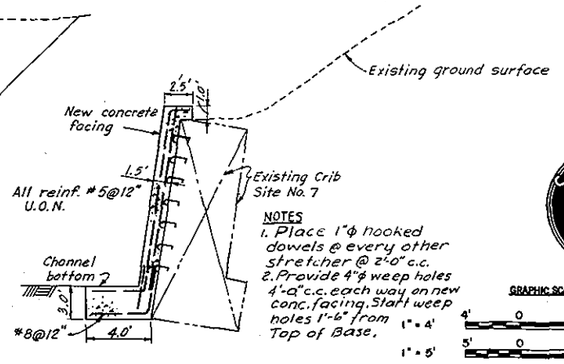
TYPICAL SECTION AT AREA (V)
SCALE: HOR. 1"=10' VERT. 1"=5'



TYPICAL SECTION AT AREA (J)
SCALE: 1"=5'



TYPICAL SECTION AT AREA (P)
SCALE 1"=5'



TYPICAL SECTION AT AREA (Q)
SCALE 1"=5'

SAFETY PAYS

GRAPHIC SCALES
1"=4' 4' 0 4' 8'
1"=5' 5' 0 5' 10'
1/2"=1'-0" 1' 0 1' 2' 3' 4' 5'

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

SUBMITTED

CHIEF, SECTION — APPROVAL RECOMMENDED

CHIEF, TECH. ENG. BRANCH — REVIEWED

PROJECT ENGINEER — APPROVAL RECOMMENDED

CHIEF, BRANCH

WATER RESOURCES DEVELOPMENT PROJECT
FITCHBURG, MASSACHUSETTS
NORTH NASHUA RIVER
CHANNEL REHABILITATION
TYPICAL SECTIONS
NORTH NASHUA RIVER — MASSACHUSETTS

APPROVED — DATE

CHIEF, ENGINEERING DIVISION

SCALE | SPEC. NO.
DRAWING NUMBER
MER-34
SHEET

PLATE 4

U. S. ARMY
CORPS OF ENGINEERS
NEW ENGLAND DIVISION

FIELD LOG OF TEST BORING

Site FITCHBURG, MASS. Page 1 of 3 Pages

Boring No. FD-1 Desig. _____ Diam. (Casing) 4" & 8"

Co-ordinates: N _____ E _____

Elevation Top of Boring 500± M.S.L.
Total Overburden Drilled 17.2 Feet
Elevation Top of Rock 483± M.S.L.
Total Rock Drilled 8.9 Feet
Elevation Bottom of Boring 474± M.S.L.
Total Depth of Boring 26.1 Feet
Core Recovered 95 % No. Boxes 1
Core Recovered 8.4 Ft. BX Diam. ____ in.
Soil Samples 2"IDx5 in. Diam. 10 No.
Soil Samples _____ in. Diam. ____ No.

Hammer Wt. 350 LBS Boring Started 5/23/77
Hammer Drop 18" Boring Completed 6/3/77
Casing Left 4" & 8"
Subsurface Water Data _____ Page _____
Obs. Well _____
Drilled By Cook (Tunnett)
Mfg. Des. Drill CP-3
Inspected By: Pendergast & Finnerty
Classification By:
Lab Classification By:

DEPTH		CORE/SAMPLE NO.	SIZE	DEPTH RANGE	BLOWS PER FT. CORE RECVY	SAMPLING AND CORING OPERATIONS	CLASSIFICATION OF MATERIALS
0.4		None	2 1/2"	0'-0.4'	47	Drove dry the 2 1/2" ID x 5' solid sampler spoon from 0.0' to 5.0' by impact of 350 lb. hammer falling 18" blow. Pulled spoon and hole reamed clean to 5.0'	TOPSOIL
0.7		T-1		0.4'-0.7'			Dark brown-grayish-silty-m-f sand moist (SM)
			I		15		
		T-2					Brown-grayish-silty-m-f sand moist (SM)
		(2)	D		8		
3.3			x	3.3'-3.3'			
			5'		7		Reddish brown-silty-c-f sandy-gravel Pulverized Ashes & Fine Cinders
		T-3					
		(1)		5.0'	7		
5.0		T-4	2"	5.0'	4	Drove dry the 2" ID x 5' solid sampler spoon from 5.0' to 10.0' pulled spoon and left 4" x 5' casing to 10.0'	Reddish Brown Silty Sandy Gravel (GM) w/Decomposed Rock
6.1		(1)	I	6.1'	6		Grey-silty-gravelly-c-f sand moist (SM) w/Gneiss
			D		7		
		T-5	x				
		(1)	5'		5		
9.4		T-6		9.9' 9.9' 10.0'	4		Grey brown-silty-c-f sandy-gravel moist (GM)
		(1)					

GENERAL REMARKS:

NED FORM MAR 71 88 (Test)

Boring No. FD-1

Plate 5

Site: FITCHBURG, MASS.	Boring No. FD-1	Page 2 of 2

DEPTH (ft)	CORE/SAMPLE NO.	SIZE	DEPTH RUNS	BLOWS PER FT. / CORE RECVY	SAMPLING AND CORING OPERATIONS	CLASSIFICATION OF MATERIALS
10.0		2" I.D. SPLIT SPOON	10.0	5	DRIVE DRY THE 2ND 10.0' SOLID SPLIT SPOON FROM 10.0 TO 14.8'. AT 14.8 SOLID REFUSAL. PULLED SPOON	DARK BROWN-SILTY-GRAVELLY-C-F SAND MOIST (SM) W/ SOLVENT ADHESIVE odor
				11		
12	F-7 (1)			24	JETTED NXW CASING TO 14.8'	
				56	SET UP TO CORE OUT REFUSAL.	GREY-SILTY-GRAVELLY C-F SAND MOIST (SM) W/ SOLVENT ADHESIVE odor
14.1			14.1			
14	F-8 (1)		14.1 14.8	152	ROTARY DIAMOND DRILLED BOULDER. RAN 1.0. REC. 0.6 60%. 37 MINUTES DRILLING TIME WATER RETURN - GREY	
14.8	B-9	NX 3 5/8 1 0 2	14.8 15.8	11" 11" CORED		BOULDER
15.8			15.8	12	DRIVE THE 2" SPOON FROM 15.8 TO 17.2'. AT 17.2 REFUSAL PULLED SPOON. JETTED BXFJ CASING TO 17.2'	BROWN-SILTY-GRAVELLY C-F SAND MOIST (SM)
16	F-10 (1)	2" I.D. x 5'		206		
17.2			17.2	18.6		
		BXM 5'	17.2	RAN 3.9'	ROTARY DIAMOND DRILLED BEDROCK FROM 17.2' TO 21.1' BARREL BLOCKED WATER RETURN - MILKY. HYD. FEED AFTER RUNNING BARREL ADVANCED BXFJ CASING BY DRILLING FROM 17.2' TO 20.4'	Diorite, dark, massive very hard coarse grained, unweathered stained and slightly weathered along low angle joints. Rock is slightly foliated at 70° dip 19.9-20.4
18				REC'D 3.5'		
	Box 1					
20				REC'D 90%		
21.1			21.1			
		BXM 5'	21.1	RAN 5.0'	ROTARY DIAMOND DRILLED BEDROCK FROM 21.1' TO 26.1' USING BXM SERIES BIT & D.T. CORE BARREL. END OF RUN WATER RETURN - MILKY HYD. FEED	
22				REC'D 4.9'		
	Box 1					
24				REC'D 98%		
26.1			26.1			
	Bottom of Boring Considered Sufficient.				Termination @ 26.1'	

Site: _____

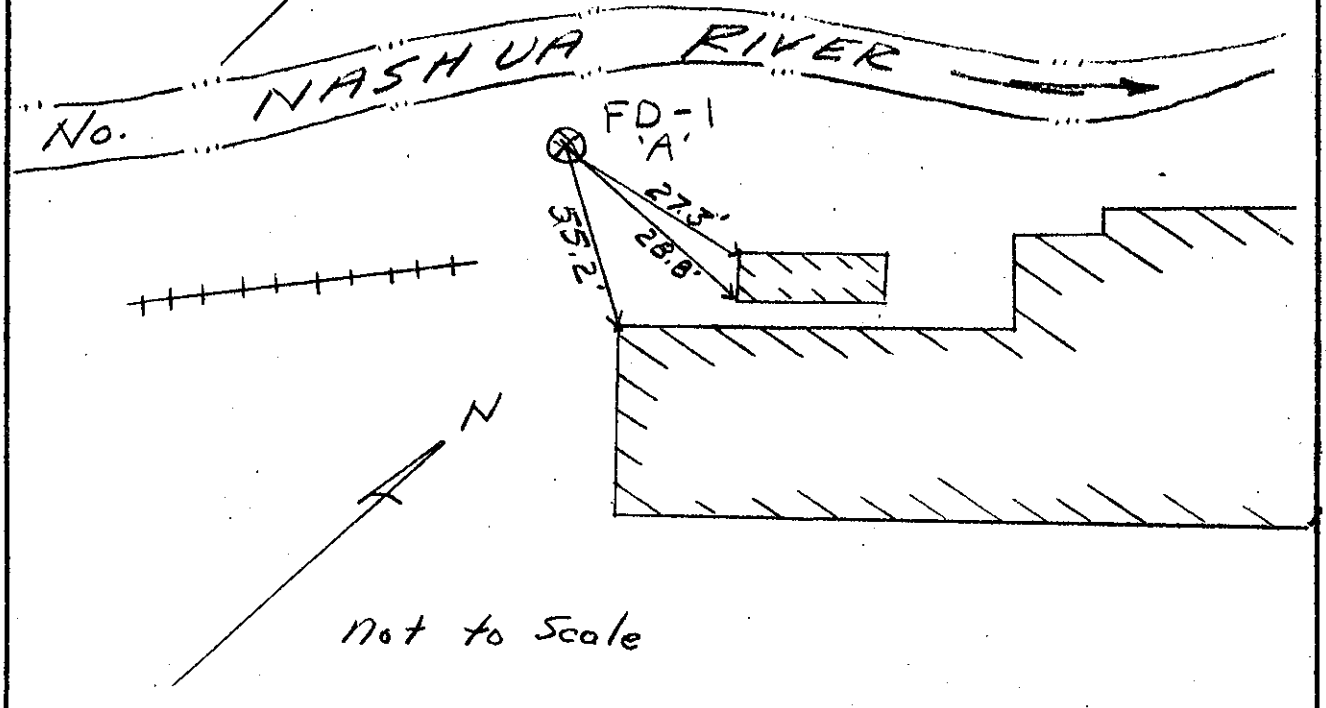
Boring No: _____

SUBSURFACE WATER OBSERVATIONS

DATE	TIME	DEPTH-BOT. OF CASING	DEPTH-BOT. OF BORING	DEPTH TO WATER	ELEVATION WATER	REMARKS

Note: Depths are in feet below original ground

BORING LOCATION SKETCH



ED FORM 59 (Test) MAR 72

Boring No. FD-1

U. S. ARMY
CORPS OF ENGINEERS
NEW ENGLAND DIVISION

FIELD LOG OF TEST BORING

Site FITCHBURG, MASS. Page 1 of 4 Pages

Boring No. FD-2 Desig. _____ Diam. (Casing) _____

Co-ordinates: N _____ E _____

Elevation Top of Boring _____ M.S.L.
Total Overburden Drilled 31.6 Feet
Elevation Top of Rock UNKNOWN M.S.L.
Total Rock Drilled NONE Feet
Elevation Bottom of Boring _____ M.S.L.
Total Depth of Boring 31.6 Feet
Core Recovered 4/10 % No. Boxes _____
Core Recovered 4/10 Ft : _____ Diam. ____ In.
Soil Samples 2½"SDS" In. Diam. 1 No.
Soil Samples 2"SDS" In. Diam. 1 No. ANB

Hammer Wt. 350 LBS Boring Started June 6, 1977
Hammer Drop 18" Boring Completed June 13, 1977
Casing Left NONE
Subsurface Water Data _____ Page _____
Obs. Well NONE
Drilled By CCCC (CONNORS)
Mfg. Des. Drill CP-3
Inspected By: MICHAEL H. PANOSSIAN
Classification By: _____
Classification By: Anthony J. Gallo

DEPTH	CORE/SAMPLE NO.	SIZE	DEPTH RANGE	BLOWS PER FT. CORE REC'VY	SAMPLING AND CORING OPERATIONS	CLASSIFICATION OF MATERIALS
1"=2						
		2½"	0.0	14	DROVE DRY THE 2½" OD x S" SOLID SAMPLE SPOON FROM 0.0 TO 5.0' BY IMPACT OF 350 LB. HAMMER FALLING 18" EACH BLOW.	BROWN-GRAY SILTY-GRAVELLY M-F SAND (SM) MOIST W/WOOD & FOREIGN MATTER
		I		16		
	T-1 (2)	O		35	BUMPED OUT SPOON AND TOOK SAMPLE.	
		X		34	HOLE CASED TO 5.0'.	
		5"	5.0	84		
5.0			5.0			
		2½		21	DROVE DRY THE 2" OD x S" SOLID SAMPLE SPOON FROM 5.0 TO 10.0	BROWN - GRAVELLY SILTY C-F SAND (SM) MOIST W/ Metal Fragment.
	T-2 (1)	I		40	BUMPED OUT SPOON AND TOOK SAMPLE.	
		O		31	DRIVED CASING TO 10.0'.	
		X	8.8	141		
8.8			8.8			
	T-3 (1)	5"	10.0	126		GREY BROWN - SILTY - C-F SANDY - GRAVEL MOIST (GM)

GENERAL REMARKS: BORING LOCATED IN SOIL AREA IN REAR OF DILLON TIRE CO. LAND, NEAR TOP OF RIVER BANK

NED FORM MAR 71 58(Test)

Boring No. FD-2

Plate 6

Site: FITCHBURG, MASS. | Boring No. FD-2 | Page 2 of 4

DEPTH		CORE/SAMPLE NO.	SIZE	DEPTH RANGE	BLOWS PER FT. CORE RECVY	SAMPLING AND CORING OPERATIONS	CLASSIFICATION OF MATERIALS
10.0		JA (1)	2"	10.0	67	DRIVE DRY THE 2" CORE SAMPLE SPOON FROM 10.0' TO 13.0'	GRAY SILTY GRAVELLY M-F SAND (SM) MOIST
			1'		92	PULLED SPOON AND TOOK SAMPLE	JA 10.0 - 10.9 BROWN SILTY SANDY GRAVEL (GM)
		T-5 (1)	0		99	JETTED NEXT CASING TO 15.0'	
			4"		344		
			5"	10.0	393		
13.0				10.0			
			2"		89	DRIVE DRY THE 2" CORE SAMPLE SPOON FROM 13.0' TO 18.0'	
		T-6 (1)	1"		237	PULLED SPOON AND TOOK SAMPLE. WASHED & CHOPPED FROM 18.0' TO 20.0'	
			0	18.0	414	JETTED NEXT CASING TO 20.0'	
18.0		NONE	4"	18.0	CHOPPED & WASHED		
			5"	20.0			
20.0				20.0			
			2"		63	DRIVE DRY THE 2" CORE SAMPLE SPOON FROM 20.0' TO 24.2'	Grey Silty fine SAND (SM) & Grey Silt (ML)
			1"		127	BUMPED OUT SPOON AND TOOK SAMPLE	
		T-7 (1)	0		120	WASHED AND CHOPPED FROM 24.6' TO 26.6'	
			4"		187	TOOK WASH SAMPLE	
			5"			JETTED NEXT CASING FROM 20.0' TO 26.6'	
24.2				24.2 WASHED CHOPPED	37		
24.6		NONE					Silty M-F SAND GRAVEL (SP-SM) WASH SAMPLE
		T-8 (1)		24.6	CHOPPED & WASHED		
26.6				24.6			

Site: FITCHBURG, MASS.	Boring No. FD-2	Page 3 of 4

DEPTH	CORE/SAMPLE NO.	CORE/SAMPLE SIZE	CORE/SAMPLE DEPTH RANGE	BLOWS PER FT. CORE RECVY	SAMPLING AND CORING OPERATIONS	CLASSIFICATION OF MATERIALS
26.6					REFUSAL AT 26.6'	
		B	26.6		ROTARY DIAMOND DRILLED OVERBURDEN FROM 26.6'	
		X		RAN 5.0'	TO 31.6' USING EXPENDABLE	
		M			BLAZE BIT & D.T. CORE	
28					BARREL.	
		5			RECOVERED 0.3' OF GRAVEL.	
	None			Rec'd 0.3'		
		P				
30		C				
		1				
		7		Rec'y 6%		
		1				
31.6		1	31.6			
					BOTTOM OF EXPLORATION AT 31.6'	
					Depth Considered Sufficient	

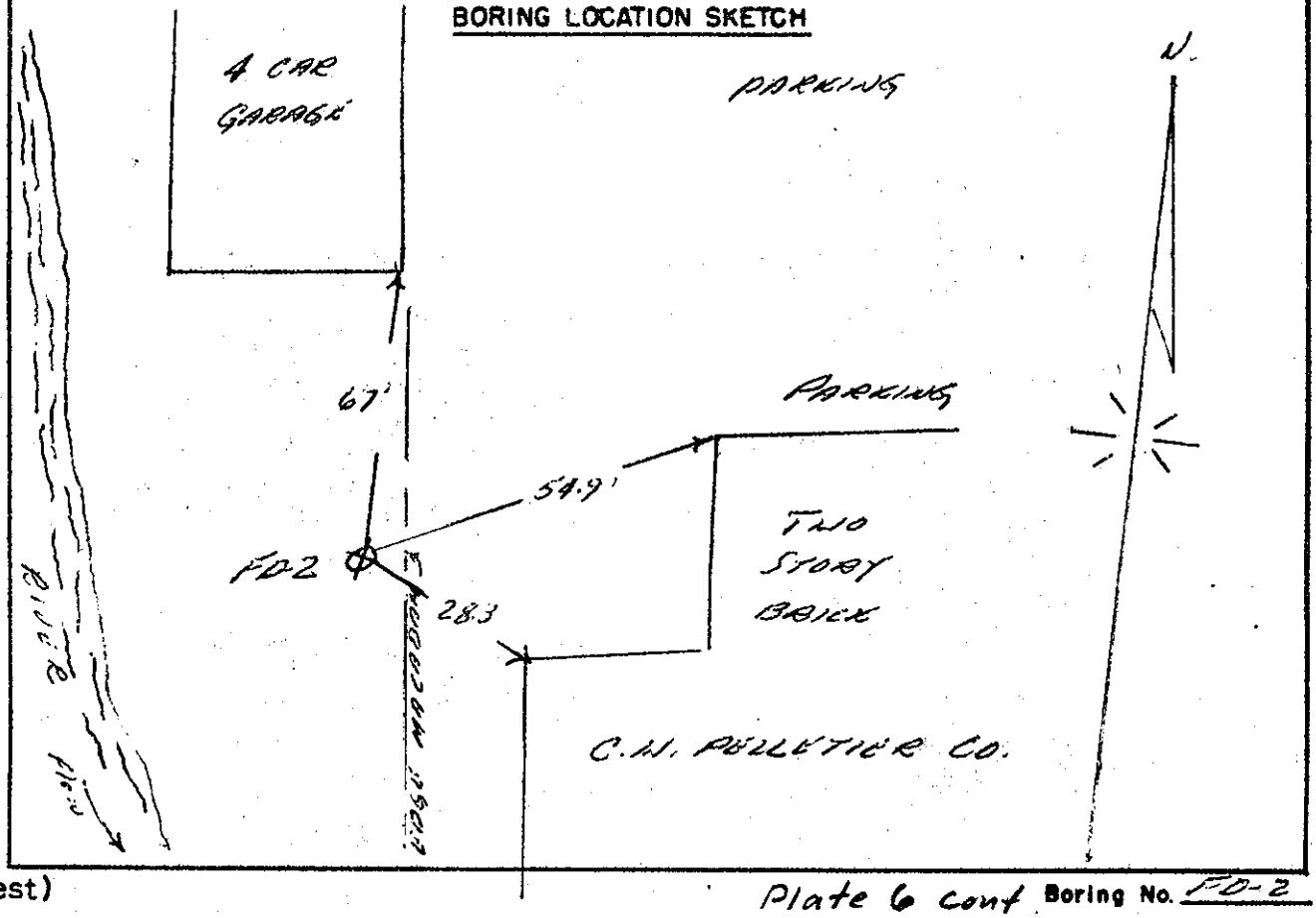
Site: FITCHBURG, MASS.
Boring No: FD-2

SUBSURFACE WATER OBSERVATIONS

DATE	TIME	DEPTH-BOT. OF CASING	DEPTH-BOT. OF BORING	DEPTH TO WATER	ELEVATION WATER	REMARKS
			RIVER LEVEL			

Note: Depths are in feet below original ground.

BORING LOCATION SKETCH



RM 59 (Test)

Plate 6 cont Boring No. FD-2

U. S. ARMY
CORPS OF ENGINEERS
NEW ENGLAND DIVISION

FIELD LOG OF TEST BORING

Site FITCHBURG, MASS. Page 1 of 4 Pages

Boring No. FB-3 Desig. _____ Diam. (Casing) NXET

Co-ordinates: N _____ E _____

Elevation Top of Boring _____ M.S.L. Hammer Wt. _____ Boring Started 16 JUNE 77

Total Overburden Drilled 28.3 Feet Hammer Drop _____ Boring Completed 23 JUNE 77

Elevation Top of Rock UNKNOWN M.S.L. Casing Left 5' CSG BIT # 2 PB 734

Total Rock Drilled NONE Feet Subsurface Water Date # NONE Page _____

Elevation Bottom of Boring _____ M.S.L. Obs. Well NONE

Total Depth of Boring 28.3 Feet Drilled By CARL (FITZGERALD)

Core Recovered 0/0 % No. Boxes _____ Mfg. Des. Drill CP-3

Core Recovered 0/0 Ft: _____ Diam. _____ In. Inspected By: RICHARD M. PRINGLE

Soil Samples _____ In. Diam. _____ No. Classification By: _____

Soil Samples _____ In. Diam. _____ No. Classification By: _____

DEPTH	CORE/SAMPLE			BLOWS PER FT.	SAMPLING AND CORING OPERATIONS	CLASSIFICATION OF MATERIALS
	NO.	SIZE	DEPTH RANGE	CORE RECVY		
	Box 1	NXW 5 3 B 1 0 6	0 to 3.0	RAN 3.0 REC'D 1.5' 0/0	ROTARY DIAMOND DRILLED THROUGH RIP RAP FROM 0.0 TO 3.0'. NATURE: BROWN 0.5' TO PIECES. HOLE DRILLED AT 20° ANGLE. DRILLED NXFS CASING TO 3.0'	
3.0			3.0			
	Box 1	NXW 5 3 B 1 0 6	3.0 to 7.2	RAN 4.2 REC'D 0.3 0/0 7	ROTARY DIAMOND DRILLED OVERBURDEN FROM 3.0 TO 7.2'. NATURE: GRAY TO BROWN PIECES DRILLED NXFS CASING OVER CORE BARREL TO 7.2'. WASHED AHEAD TO 7.6'	
7.2'			7.2			
	Box 1	NXW 5 3 B 1 0 6	7.2 to 11.5	RAN 3.9 REC'D 1.5' 0/0 40	ROTARY DIA. DRILLED OVB. FROM 7.2 TO 11.5'. NATURE: BROWN ROTARY DRILLED CASING OVER CORE BARREL TO 11.5'. BIT # 2 PB 734	
11.5'			11.5			

GENERAL REMARKS: HOLE DRILLED AT AN ANGLE OF 20° THROUGH CRIBBING ON BANK OF RIVER. HOLE LOCATED IN CENTER OF CRIBBING ON UP TRON RIVER BOTTOM

NED FORM MAR 71 58(Test) Boring No. FB-3 Plate 7

Site: FITCHBURG, MASS. | Boring No. FD-3 |

DEPTH	Ft.	CORE/SAMPLE NO.	SIZE	DEPTH RANGE	BLOWS PER FT. / CORE REC'VY	SAMPLING AND CORING OPERATIONS	CLASSIFICATION OF MATERIALS
10.0		Box 1	7.2 / 11.5	NXM 53B106	RAN 3.9 REC'D 1.5' REC'Y 40%	1.1 TO GRAVEL	
11.5'		Box 1	NXM 53B106	11.5–15.9	RAN 4.4 REC'D 2.5' REC'Y % 57	ROTARY DIAMOND DRILLED OVB. FROM 11.5' TO 15.9' WATER: WHITE TO BROWN. DRILLED NXFJ CASING OVER BARREL TO 15.9'. 1.4' TO GRAVEL	
15.9'		Box 1	NXM 53B106	15.9–20.9	RAN 5.0 REC'D 0.5' REC'Y % 10	ROTARY DIAMOND DRILLED OVB. FROM 15.9' TO 20.9 WATER: BROWN DRILLED NXFJ. CASING OVER BARREL TO 20.9' GRAVEL	
20.9		Box 1	NXM 53B106	20.9–25.9	RAN 5.0 REC'D 0.0 REC'Y % 0	ROTARY DIAMOND DRILLED OVB. FROM 20.9' TO 25.9. WATER: 100% LOSS. DRILLED NXFJ CASING OVER BARREL TO 25.9' CORE BARREL STUCK IN CASING. NO RECOVERY.	
25.9						DRILLED NXFJ CASING AHEAD OF BARREL FROM 25.9' TO 28.3'	

Site: FITCHBURG, MASS.	Boring No. EO-3	Page 3 of 4

DEPTH		CORE/SAMPLE			BLOWS PER FT. CORE RECVY	SAMPLING AND CORING OPERATIONS	CLASSIFICATION OF MATERIALS
	ft.	NO.	SIZE	DEPTH RANGE			
27.4	3	NONE	NX CSG	25.4 / 28.3	NONE	DRILLING BEHAVIOR SIMILIAR TO OUB. CASING WOULD NOT ADVANCE BEYOND 28.3'. CASING SEPARATED AND LEFT 5' OF CASING IN HOLE WITH CSG. BIT. 2PB734	
28.3'						BOTTOM OF EXPLORATION @ 28.3. TOOLS STUCK IN HOLE	

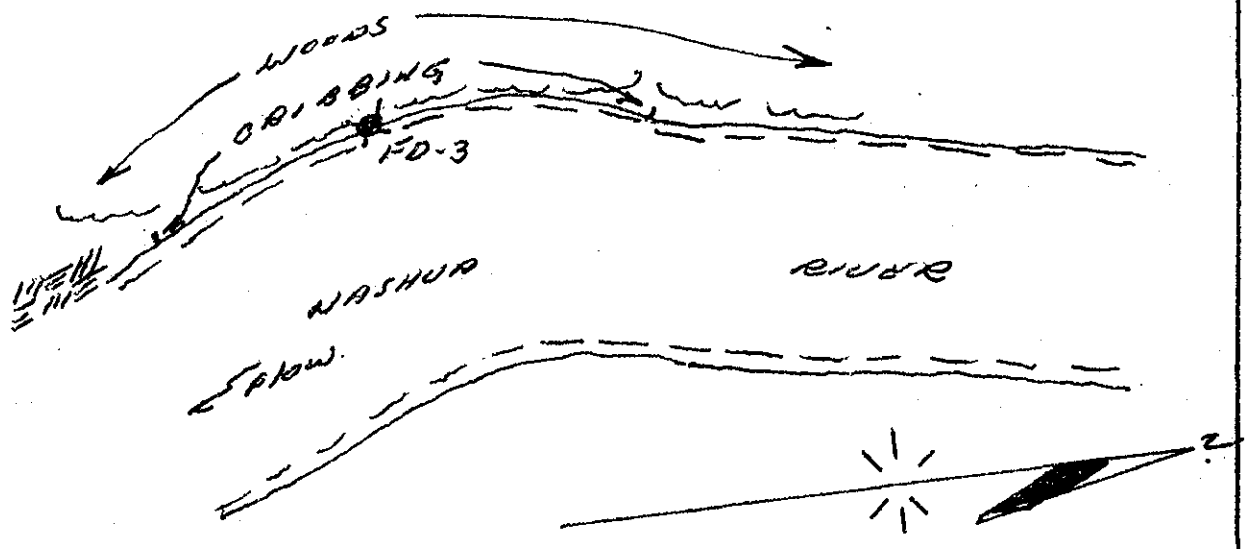
Site: FITCHBURG, MASS.
Boring No: FD-3

SUBSURFACE WATER OBSERVATIONS
PAGE 4 OF 4

DATE	TIME	DEPTH-BOT. OF CASING	DEPTH-BOT. OF BORING	DEPTH TO WATER	ELEVATION WATER	REMARKS
			AUGER	HOLE		

Note: Depths are in feet below original ground

BORING LOCATION SKETCH



HOLE LOCATED IN CENTER OF CRIBBING 0.4' UP FROM RIVER BOTTOM ON 20° ANGLE 70° OFF VERTICAL.

V. PELLETIER
DRYWALL & PLASTERING.

FORM 59 (Test)
AR 715-2

Plate 7 cont. Boring No. FD-3

ATTACHMENTS

ATTACHMENT A

LETTERS OF COMMENT AND CONCURRENCE

THE COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE DEPARTMENT
STATE HOUSE • BOSTON 02133

MICHAEL S. DUKAKIS
GOVERNOR

September 13, 1976

Colonel John P. Chandler
Division Engineer
U. S. Army Corps of Engineers
New England Division
424 Trapelo Road
Waltham, MA. 02154

Dear Colonel Chandler:

This is in response to Colonel Mason's letter of August 16, 1976, in which he requested the Commonwealth's support of the revised flood protection plan (the so-called revised "EQ" plan) for the North Nashua River Basin. In his letter, he indicated that prior to the Corps pursuing any further activities on this revised plan of protection, it was essential that the Corps receive such an expression of support from me. The purpose of this letter is to inform you that I endorse the implementation of the revised "EQ" plan for the North Nashua River Basin, provided a number of salient concerns are properly addressed throughout the development and construction process.

The need for protection against flooding in the North Nashua River Basin is clear. Many years of planning for flood protection in the basin resulted in the creation of the 1965 "NED" plan, designed to provide protection against flooding higher than the level of the 100 year flood. The revised "EQ" plan is a modification of this original plan and was prepared in response to the legitimate concerns of residents of the affected communities. I would have preferred a non-structural solution to the problem. However, steep stream gradients in the North Nashua River and the virtual absence of natural storage in the basin create a situation of very rapid runoff which preclude this alternative. I am now satisfied that all possible alternatives for the control of flood waters in the basin have been considered and that structural solutions are required to provide protection from flood waters.

ATTACHMENT A-1

This decision has not been an easy one. I am sensitive to the involvement and concern of the people of the North Nashua River Basin and believe that their role is critical in shaping this plan. It is my expectation that any and all future design activities will be undertaken in a manner which gives full consideration to the social, economic, and environmental concerns of the residents of those communities and of the entire Montachusett Region. To insure this, I would expect the Corps to establish liaison committees in both Westminster and Fitchburg composed of state and local officials and private citizens to jointly plan those aspects of the project which are of continuing concern to the affected communities.

A primary issue which the Corps should seriously consider is the feasibility of developing the final design plan for the Phillips Dam prior to the commencement of construction and related activities on the Whitmanville Dam. This is in response to strong and reasonable expressions of concern by the citizens of Westminster who wish to mitigate, to the extent possible, the impacts upon their community.

The construction of Phillips Dam serves as an excellent opportunity to provide needed water-based recreation for the citizens of Fitchburg. Design criteria for recreational facilities at the Phillips Lake site in Fitchburg should be developed in cooperation with the appropriate municipal and state agencies.

The Corps should also work closely with the Fitchburg Conservation Committee in order to provide urban river-based recreational opportunities along the restored channel. As the channel restoration design effort proceeds, the project should be viewed as an outstanding opportunity not only to increase channel carrying capacity, but also to develop a pedestrian walkway or linear park through the city. I am sure that the October 5, 1976 public meeting on restoration of the new channel will serve as the forum where such coordinated planning can commence.

The anticipated realignment of affected roadways (including Route 12) presents an opportunity to improve traffic circulation in the affected areas. I expect that the Corps will work closely with the involved municipalities in developing a circulation pattern which benefits both the residents and businesses of the North Nashua River Basin.

With regard to resident dislocation, I would strongly urge that you work closely with affected households and businesses in arriving at a relocation plan that is responsive and minimally disruptive. Specifically, you may find that the individuals affected desire takings at the earliest possible date in order to maximize their options regarding future relocation decisions. In conjunction with this, you should seriously consider the possibility of allowing families and businesses to remain after taking until such time that actual construction commences.

Col. John P. Chandler
September 13, 1976

In closing, I am acutely sensitive to the attitudes of the communities, individuals, and businesses affected by the proposed actions. At the same time, there appears to be a greater public purpose involving the physical safety and economic well-being of all inhabitants of the North Nashua River Basin. A recurrence of the 1936 flood level could cause property losses of over $42 million and could disrupt or eliminate over 10,000 jobs as well as pose a threat to the lives, health, and homes of area residents. For these reasons, I support your request for funds with the knowledge that you will accord maximum consideration to the concerns expressed in this letter.

Sincerely,

MICHAEL S. DUKAKIS

MSD/cam

cc: Senator Edward M. Kennedy
Senator Edward W. Brooke
Congressman Robert F. Drinan
Mayor Hedley Bray
Board of Selectmen, Town of Ashburnham
Board of Selectmen, Town of Westminster
Secretary Evelyn Murphy, Environmental Affairs
Secretary Howard Smith, Economic Affairs
Secretary Christine Sullivan, Consumer Affairs
Secretary William Flynn, Communities and Development
Director Frank Keefe, Office of State Planning
Councillor Bernard Chatrand, City of Fitchburg
Mrs. Marion Stoddard
Representative Robert Wetmore
Senator Robert Hall
Mrs. Mary Vedoe, Westminster Conservation Commission
Mrs. Madeline Gaylor, Fitchburg Conservation Commission
Concerned Citizens of Westminster c/o George Wallin
George Glasson, Montachusett Regional Planning Commission

BERNARD F. CHARTRAND
President, City Council

City of Fitchburg

Massachusetts 01420

Board of City Council

December 16, 1976

Col. John P. Chandler
Department of the Army
New England Division
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Col. Chandler

Enclosed herewith is a copy of a resolution passed by the Fitchburg City Council in formal session on December 15, 1976.

Your kind consideration in this matter is respectfully requested.

Very truly yours

Bernard F. Chartrand

Bernard F. Chartrand
President, City Council

ATTACHMENT A-2

BFC:s
Enc.

PRESENTED TO THE MAYOR

For approval December 16, 1976

Irene Bordenave
City Clerk.

MAYOR'S OFFICE

Fitchburg, Mass., Dec 16, 1976

APPROVED

Healey Bray
Mayor.

A True Copy Attest:

Irene Bordenave

Irene Bordenave
City Clerk

No. 757 - 76

RESOLUTION
ORDER

In re Channelization Project

In City Council,

December 15, 1976

Resolution ~~Order~~ read and adopted under suspension of the rules by uhanimous vote. 11 members present. Board consists of 11 members.

Irene Bordenave, Clerk

City of Fitchburg

16 Dec 70

In City Council,

RESOLVED:-
ORDERED:- That WHEREAS, the City Council of the City of Fitchburg recognizes that cooperation between the U. S. Army Corps of Engineers, officials and citizens of Fitchburg is required to improve the safety and quality of life for the residents of Fitchburg, and

WHEREAS, flood protection in the City of Fitchburg is a major priority and said priority deserves utmost consideration

NOW, THEREFORE, BE IT RESOLVED that the Fitchburg City Council be recorded as favoring the Channelization Project and that it be first completed and reviewed prior to approval of any subsequent construction of dams, and that funds be made available for a complete restoration, starting at the West Fitchburg Wastewater Treatment Plant, following the natural course of the river to the East Wastewater Treatment Plant.

A True Copy Attest:

Irene Bordenave

Irene Bordenave
City Clerk

David J. Chartrand
Council President

CITY OF FITCHBURG

EXECUTIVE DEPARTMENT

Mayor
Hedley Bray

Administrative Assistant
Daniel C. Croucher

August 22, 1977

Ralph T. Garver
Colonel, Corps of Engineers
Acting Division Engineer
424 Trapelo Road
Waltham, Massachusetts 02154

Re: Local Flood Protection Rehabilitation
of Channel North Nashua River
Fitchburg, Massachusetts

Dear Colonel Garver:

It is the intent of the City of Fitchburg that the Corps of Engineers proceed with the rehabilitation of the North Nashua River in Fitchburg as outlined in a letter from the Corps dated August 8, 1977 namely;

a. The continuance of further design and preparation of contract documents for the project and its ultimate funding and construction by the Government.

b. That prior to the initiation of construction of the restoration project, tentatively scheduled for the Fall of 1978, the City of Fitchburg will provide the necessary items of local cooperation. These items of local cooperation include the following:

1) Provide, without cost to the United States, all lands, easements, and rights of way necessary for the construction and maintenance of the project.

2) Hold and save the United States free from damages due to the construction work, except where such damages are due to the fault of the United States or its contractors.

3) Maintain and operate the project after completion.

4) Provide without cost to the United States all alterations and replacements of existing utilities where necessary.

I also understand that the project will be within the same property limits as the 1936 project and it is noted that this Division does not envision any additional land acquisitions for the project, nor is it anticipated that there will be any alterations, replacement or relocation of utilities required. A preliminary estimate of annual cost to the city for maintaining the channel after completion is $5,400. This amount covers removal of debris, vegetation control, and miscellaneous channel maintenance activities only.

Very truly yours,

Hedley Bray

Hedley Bray, Mayor

CITY HALL, 718 MAIN STREET, FITCHBURG, MASS. 01420
TELEPHONE (617) 343-4821

ATTACHMENT A-3

ATTACHMENT B

PROJECT COST AND ESTIMATE

REASONABLE CONTRACT ESTIMATE

NORTH NASHUA RIVER
FITCHBURG CHANNEL REHABILITATION

ITEM NO.	DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	ESTIMATED AMOUNT
A	Place 36" rock slope protection for 200' and remove random boulders	1	Job	L.S.	$ 60,000
B	Remove loose stonewall above El495 and rebuild cut stonewall in adjacent location	1	Job	L.S.	5,000
C	Regrout cut stonewall for a destance of ± 100 ft.	1	Job	L.S.	4,000
D	Install 18" diameter pipe for sewer, remove boulders	1	Job	L.S.	5,000
E	Repair channel bottom by grouting cut stones at bottom	1	Job	L.S.	5,000
F	Crib Site No. 1- to be removed Build new wall. Crib Site No.2	1	Job	L.S.	93,000
	to be removed. Build new wall	1	Job	L.S.	95,000
G	Repair grouted riprap and wingwall	1	Job	L.S.	10,000
H	Remove large stone or reposition stone	1	Job	L.S.	4,000
I	Reset large stones and put in wellgraded riprap	1	Job	L.S.	3,000
J	Crib Site No. 3 - Put in larger size riprap and cover crib site	1	Job	L.S.	44,000
K	Repair ± 100' of base of wall	1	Job	L.S.	7,000
L	Repair eroded grouted riprap	1	Job	L.S.	5,000
M	Crib Site No.4 - Install a concrete cap and resurface eroded stretcher members	1	Job	L.S.	8,000
N	Cap concrete wall on south bank	1	Job	L.S.	9,000

REASONABLE CONTRACT ESTIMATE (CONT'D)

ITEM NO.	DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	ESTIMATED AMOUNT
O	Crib Site No. 5 - Replace with concrete wall	1	Job	L.S.	$ 76,000
	Crib Site No. 6 - Replace with concrete wall	1	Job	L.S.	50,000
P	Restore 110' concrete wall	1	Job	L.S.	92,000
	Remove and reposition stones	1	Job	L.S.	3,000
	Sandblast wall and paint fence	1	Job	L.S.	4,000
Q	Crib Site No. 7 - Install a 1.5' concrete veneer over crib facing	1	Job	L.S.	83,000
R	Repair openings in steel sheeting	1	Job	L.S.	2,000
S	Reset large stones on downstream apron	1	Job	L.S.	2,000
T	Remove two midstream bridge piers; regrout left bank abutment	1	Job	L.S.	10,000
U	Reset large stone	1	Job	L.S.	3,000
V	Riprap Syphon dam area	1	Job	L.S.	291,000
	Grouted Riprap at Bridge Piers	1	Job	L.S.	8,000
	Remove Shoaling	1	Job	L.S.	84,000
	Remove Trees and Brush	1	Job	L.S.	63,000
	Bulldoze-River Bottom	1	Job	L.S.	150,000
	Topsoil, Seed, Landscape	1	Job	L.S.	42,000
					$1,320,000
	±25% Contingencies				330,000
	Total Direct Cost				$1,650,000
	Engineering & Design				280,000
	Supervision & Administration				170,000
	Total Project First Cost				$2,100,000

ATTACHMENT B

ATTACHMENT C

SECTION 404 EVALUATION REPORT

PRELIMINARY

SECTION 404 EVALUATION REPORT

FOR

CHANNELIZATION REHABILITATION PROJECT

LOCAL FLOOD PROTECTION

NORTH NASHUA RIVER

FITCHBURG, MASSACHUSETTS

Prepared By
Department of the Army
New England Division, Corps of Engineers
Waltham, Massachusetts 02154

TABLE OF CONTENTS

Attachments

NOTE:

This is a Preliminary issue of 404 Evaluation Report prepared in accordance with the provisions of ER 1105-2-XXX dated 1 October 1977.

Following appropriate public notice and responses, a final 404 Evaluation Report will be issued as a Supplement to this GDM

Section 404 Evaluation Report
for
Channelization Rehabilitation Project
Local Flood Protection
North Nashua River
Fitchburg, Massachusetts

1. References

a. Section 404(b) of Public Law 92-500, Federal Water Pollution Control Act Amendments of 1972 as enacted on 18 October 1972 pertaining to the water quality considerations of discharge of dredged or fill material into waters of the United States.

b. Corps of Engineers Circular, EC 1165-2-125, dated 31 January 1977.

c. 40 CFR 230.4-230.5 dated 5 September 1975.

2. Background

The channel project was originally authorized in 1936 and construction was completed by the Corps of Engineers in 1937. Over the years the project has deteriorated, above normal operation and maintenance, to a point where major restoration of the project is necessary so it can fulfill its original design function.

3. Work Under Proposed Project

The work under the proposed project involves, in general, the following:

a. Reconstruction or replacement of all walls and cribs downstream of River Street and Circle Street, upstream of Putnam Street, upstream and downstream of the Boston and Maine Railroad Bridge at Laurel Street and upstream of the Water Street Bridge.

b. Rehabilitation of grouted riprap at bridge piers, wall footings and other critical locations. In various areas from Oak Hill Bridge downstream to the Falulah Road Bridge, existing riprap may be replaced with concrete or stone protection of adequate size.

c. Channel obstructions and depositions now obstructing the channel would be removed. Considerable scouring of riprap has occurred from Oak Hill Road to Laurel Street along the North Nashua River. Movement of stone impedes channel flows by greatly increasing friction values along the channel. The plan calls for the removal of this stone and replacement of riprap where necessary. Stone protection would be provided to prevent further erosion and undermining of the bank during future floods.

The overall project involves reshaping the channel bottom and reutilization of streambed materials and/or removed and replaced with new concrete floodwalls. The sand and gravel shoaling and stone deposits and/or the material in the bottom of the channel will be reutilized in the general reshaping and protection of the channel bottom. There will be no dredging of materials which have collected behind the five privately owned dams in the project area nor in the private storage pools at the dams. It is noted that the dammed water is used principally for manufacturing processing and fire protection purposes in the plants.

The general cleanup of the river will consist of the removal of solid waste types of debris which has collected in the streambed and on the banks. There is not a great deal of this material but it consists of a few discarded shopping carts, vehicular tires, wooden boxes, miscellaneous boards and poles, as well as selected vegetation which is to be cut and removed from the project site under the proposed work. These items of debris will be removed and placed in an approved local landfill location and be accomplished under the terms of the proposed rehabilitation contract.

4. Status of the Project

A Survey Scope Report for overall flood protection measures in the North Nashua River Basin was prepared in January 1965. The channel improvements was one of the elements of the plan which also included proposed dams and reservoirs at Phillips, Whitmanville and Nookagee, which are upstream of the channel site.

The projects were authorized by the PL89-789, Flood Control Act of 1966, however, public decision to construct the dams and reservoirs has not been reached. None of the overall flood protection items have been funded or constructed to date. The channel rehabilitation project will be the first in this category.

Currently a combined Phase I, Plan Formulation and Phase II, General Design Memorandum is being prepared on the channel project and this Section 404 Evaluation Report is based on the present stage of the project. As the preparation of plans and specifications progresses and the project goes into construction the necessary updating and revisions to the Evaluation Report will be made. At this time the project is in Category A - "Projects for Which a Phase I General Design Memorandum has not been approved as of the date of this circular." (EC 1165-2-125, dated 31 January 1977).

5. Environmental Concerns

In view of the fact that the work is a rehabilitation of an existing project and there is no change in realignment or deepening of the streambed, it is considered a minor action project and an Environmental Assessmant is being prepared in lieu of an Environmental Impact Statement.

There are no permanent and/or irreversible environmental impacts caused by the project. Environmental impacts will take place only temporarily during the construction operations,such as production of turbidity. No conservation groups or others are known to oppose the proposed rehabilitation at this time.

6. Public Involvement

On 5 October 1976 a public meeting was conducted in Fitchburg, Massachusetts by the New England Division, Corps of Engineers during which the project was presented including a Summary of Environmental Considerations.

The project does involve work in the river streambed including removal of debris, reconstruction, removal/relocation of boulders and riprap, and reshaping of the channel bottom. Shoal areas shall be regraded and material removed as necessary. Some of the shoal material may be reutilized in the grading operation. This public meeting did not specifically address Section 404 of PL 92-500.

7. Technical Evaluation

A technical evaluation of the project with respect to environmental impacts has been made and the results and findings are presented herein.

In accordance with EC 1165-2-125 dated 31 January 1977, the North Nashua River Channel Rehabilitation Local Protection Project has been reviewed. From this review, I have determined that no unresolved concerns exist. The public and interested Federal agencies have had an opportunity to express themselves during the planning stages of the project. The interim final guidelines of the Environmental Protection Agency for the discharge of dredged or fill material (40 CFR 230.4-230.5, 5 September 1975) which covers the discharge of dredged or fill material in navigable waters have been reviewed. For this project the area of the river bottom to be reshaped and regraded is approximately 50' wide in various locations in the five mile reach of the North Nashua River in Fitchburg, Mass. Other items of work are the construction of floodwalls, repairs to existing walls and other miscellaneous construction activities.

230.4-1 Physical and Chemical-Biological Interactive Effects

The fill material is composed predominantly of sand, gravel and former processed quarried rock that presently exists in the streambed and which has shoaled and become displaced. The new borrow material required behind floodwalls will be sand and gravel from acceptable private sources.

See attached table for factors considered and remarks on the technical evaluation.

TABLE FOR TECHNICAL EVALUATION
NORTH NASHUA RIVER CHANNEL REHABILITATION
FITCHBURG, MASSACHUSETTS

40CFR230 Reference Paragraph*	Factors Considered	Remarks
230.4-1(a)(1)	Destruction of highly productive wetlands	Not applicable, The river and/or wetlands will not be filled. The shape of the existing channel will be restored to its original designed shape. There is no new alignment.
230.4-1(a)(2)	Effects on the water column	The work will be accomplished in the dry as much as possible during low flow periods of the year. Temporary diversions will also be used in the channel.
230.4-1(a)(3)	Effect on the benthos	The effect on the benthos is minor as there are no known fresh water bottom dwelling organisms of any significance in this reach of the river.
230.4-1(b)	Chemical-Biological interactive effects	No new fill material will be utilized. Existing sand, gravel and stone in the river bottom will be regraded to provide a level bottom and better flow in the channel.
230.4-1(c)	Comparison of sites	The Bureau of Sport Fisheries and Wildlife stated that the project will have no adverse effects upon the fish and wildlife resources.
230.4-2	Water quality considerations	Although no long term adverse effects on water quality are anticipated as a result of the proposed project, short term detrimental effects may occur as a result of increased turbidity and siltation resulting from construction operations. Siltation will be controlled by temporary measures to minimize erosion and sedimentation, such as, berms, dikes, drains, immediate seeding of cut or fill slopes or sedimentation basins. This portion of the river has been classified by the Federal Water Quality Administration as Class C, which standard it is anticipated will not be violated by this project. Present condition of the river is unsatisfactory "U". (See Section AD of GDM No. 1)

*See note on last page.

TABLE (Cont'd)

Reference Paragraph	Factors Considered	Remarks
230.5-(a)	Selection of disposal sites and conditioning of discharges of dredged materials. General considerations and objectives.	All of the river bottom material which is not reutilized will be removed and placed in accepted local disposal landsites.
230.5-(a)(1)-(8)	Selection of disposal sites and conditioning of discharges of dredged materials. General considerations and objectives.	(1) The reused bottom material will be placed under dry conditions as the stream will be diverted during the rehabilitation work. (2) There will be minor disruption to the food chain of plant and animal species in the stream. (3) Construction will have little effect on the movement of terrestrial which may feed fauna, spawn or breed in this area. (4) The river channel has no significant function in maintenance of water quality. (5) Flood heights will not be altered. The project will prevent flooding of industrial, commercial and residential properties along the banks of the river. (6) Turbidity occurring during construction is expected to be monor and short term. (7) The esthetics of the area will be enhanced by the project. The revegetation of the channel area offers an opportunity to better the esthetic quality. Since the environment is mostly manmade, consisting of factories, etc., the improvements will not detract anything from the scenery. Instead, neatness, control and order will displace an unsightly and undesirable condition.

TABLE (Cont'd)

Reference Paragraph	Factors Considered	Remarks
		(8) All filling will be done under dry conditions after diversion of water; therefore, impact on water quality will be minor.
230.5-(b)(1)-(10)	Considerations relating to degradation of water uses at proposed disposal sites.	(1) There are no municipal water supply intakes nearby. (2) The project is not located in an area of concentrated shellfish production. (3) The project will have no adverse effect on fish resources, a. Significant fish spawning or nursery areas are not involved. b. Spawning cycles and migration patterns and routes will not be appreciably affected by this project. c. There is no appreciable amount of submerged vegetation at the site. (4) Wildlife - There are no adverse effects on wildlife resources. (5) Recreation activities, a. Increases in turbidity will only occur for short periods. b. Release of nutrients from dredged or fill material not applicable for project. c. No pathogenic organisms are expected to be found in the fill material. d. Fill material will be free of oil and grease.

TABLE (Cont'd)

Reference Paragraph	Factors Considered	Remarks
		(6) There are no known threatened or endangered species which might be affected by this project.
		(7) Disposal of excavated material will be at a land-fill site approved by the Contracting Officer.
		(8) The proposed fill within the former riverbed and construction work associated with it will not cause a permanent unacceptable disruption to the beneficial water quality uses of the affected aquatic system.
		(9) There is no significant submersed vegetation at the project site.
		(10) Size of disposal site. (Note: See (7) above).
230.5-(c)(1)-(2)	Other considerations in determining its site and disposal conditions	(1) Federal Water Quality Administration has stated that the project will have no long term adverse effects on the water quality.
		(2) Upland disposal sites will be approved by the Contracting Officer.
		(3) Disposal sites will be approved upland landfill sites.
		(4) Open water disposal is not applicable to this project.
		(5) Covering contaminated dredged material not applicable to this project.
		(6) Runoff from confined areas will not affect the project.
		(7) Not applicable. Monitoring not deemed necessary.

TABLE (Cont'd)

Reference Paragraph	Factors Considered	Remarks
230.5-(d)	Contaminated fill material restrictions	Not applicable. Fill materials are not required in streambeds. Fill materials to be placed in back of new floodwalls will be uncontaminated material obtained from local commercial sources.
230.5-(e)	Mixing zone determination	This section refers to water disposal sites and is not applicable to this project.

*Notes:

1. The paragraph references are those contained in the 40 CFR 230. Refer to the project Environmental Assessment dated November 1977, prepared by the New England Division for environmental considerations.

2. The General Design Memorandum No. 1 for the project, dated December 1977 also contains applicable data to the Section 404 requirements. Sections G, I, L, N, U, V, AD, and AF may be referred to.

ATTACHMENT D

STRUCTURAL COMPUTATIONS

SUBJECT ATTACHMENT "D"

COMPUTATION _____

COMPUTED BY _____ CHECKED BY _____ DATE _____

NORTH NASHUA R. — STRUCTURAL COMPUTATIONS

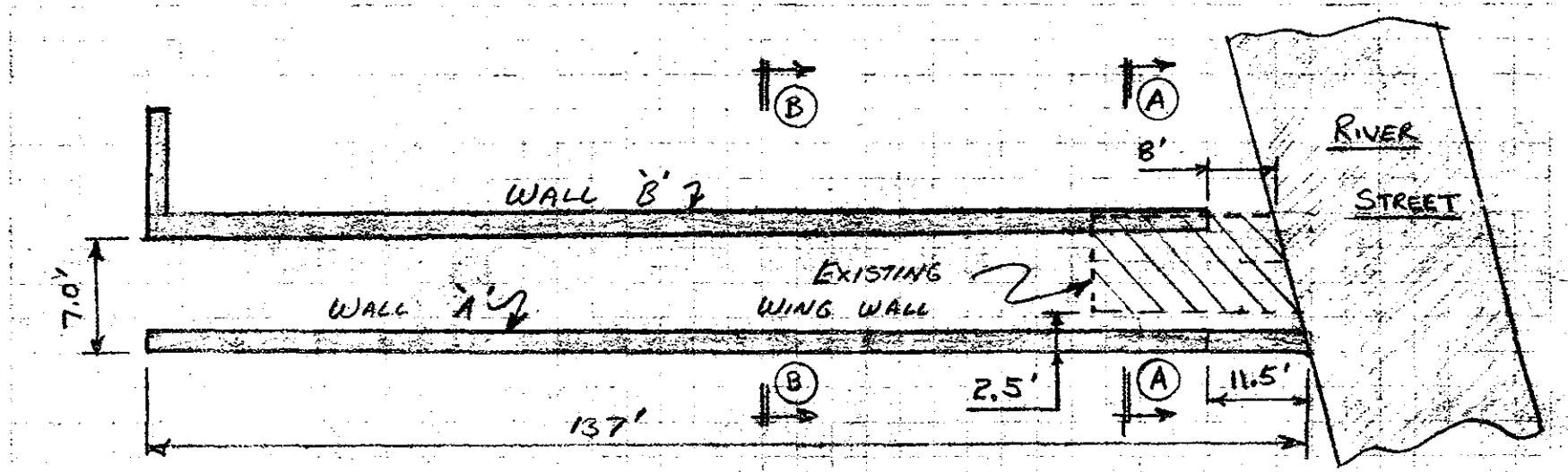
TABLE OF CONTENTS

DIMENSIONS SCALED FROM CIVIL LAYOUT DRAWINGS BY IRV ROUNDS.

NED FORM 223
27 Sept 49

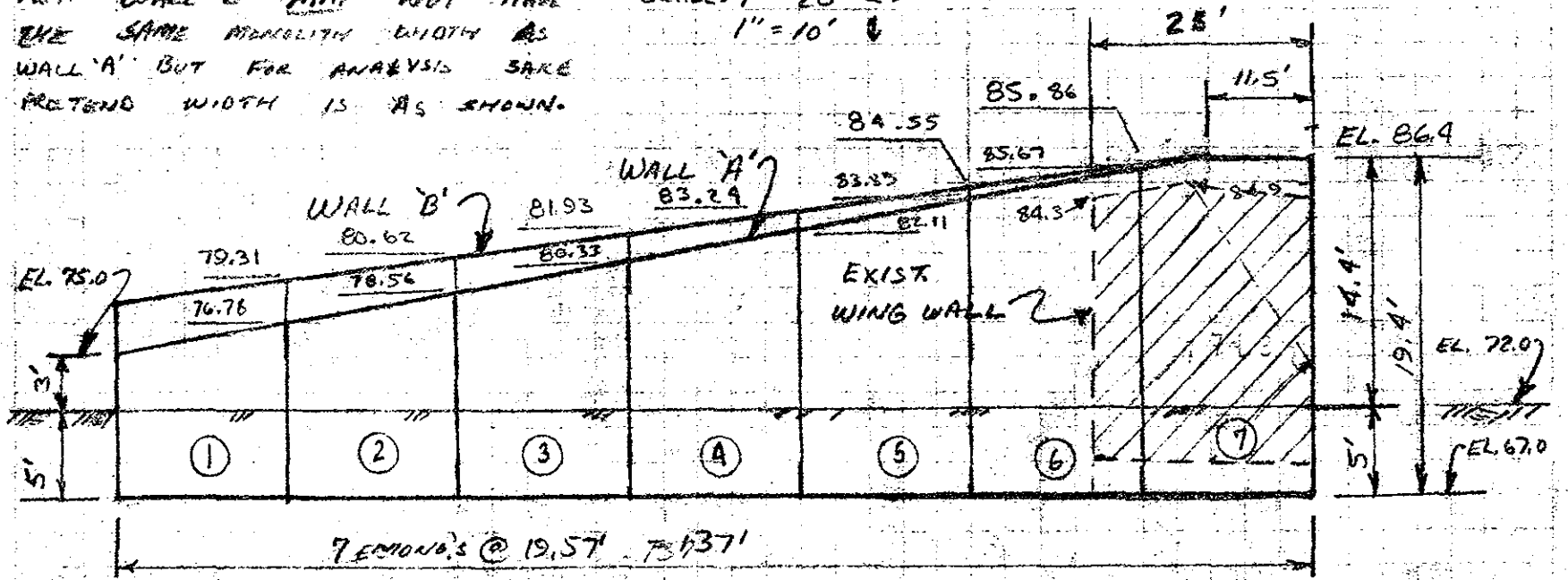
NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U.S. ARMY

SUBJECT No NASHUA
COMPUTATION CRIB SITE #2
COMPUTED BY VF
CHECKED BY
DATE 6-7-77
PAGE 1



PLAN - CRIB SITE #2
SCALE: 1" = 20' ↔
1" = 10' ↕

Note: WALL 'B' MAY NOT HAVE THE SAME RETAINING WIDTH AS WALL 'A' BUT FOR ANALYSIS SAKE PRETEND WIDTH IS AS SHOWN.



ELEVATION
SCALE: 1" = 20' HORIZ.
1" = 10 VERT.

SUBJECT N. NASHUA

COMPUTATION CS #2 2

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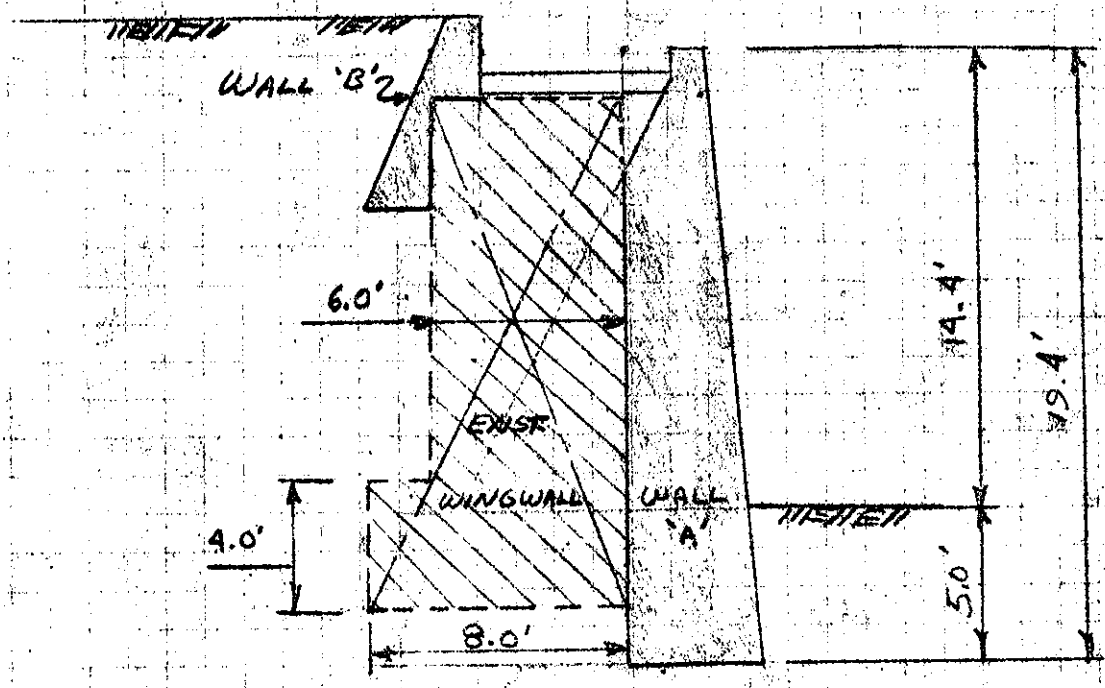
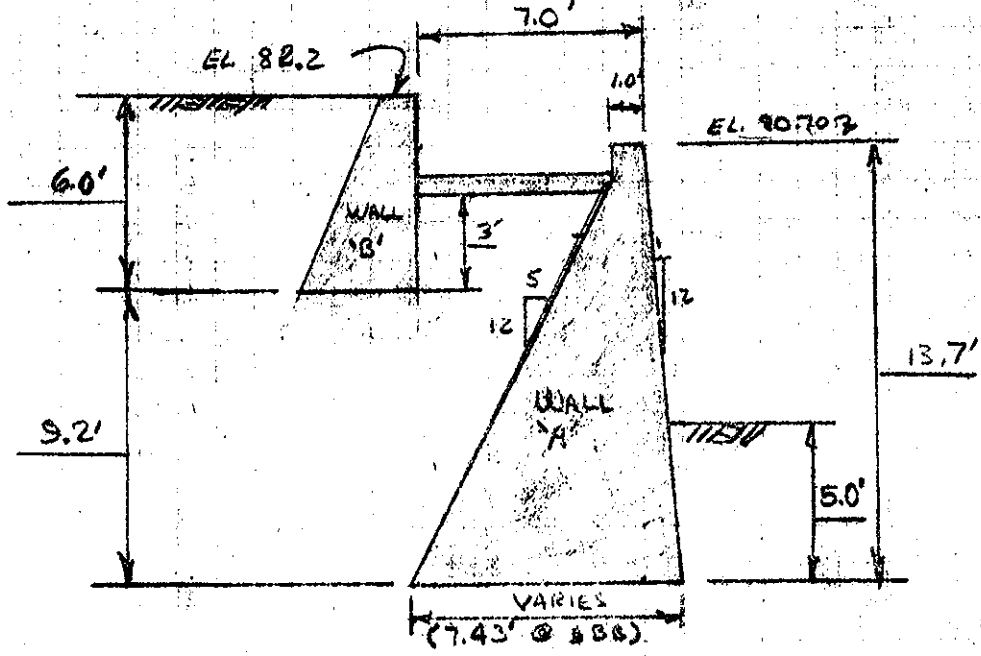


SECTION (A)(A)
SCALE: 1" = 6.0'



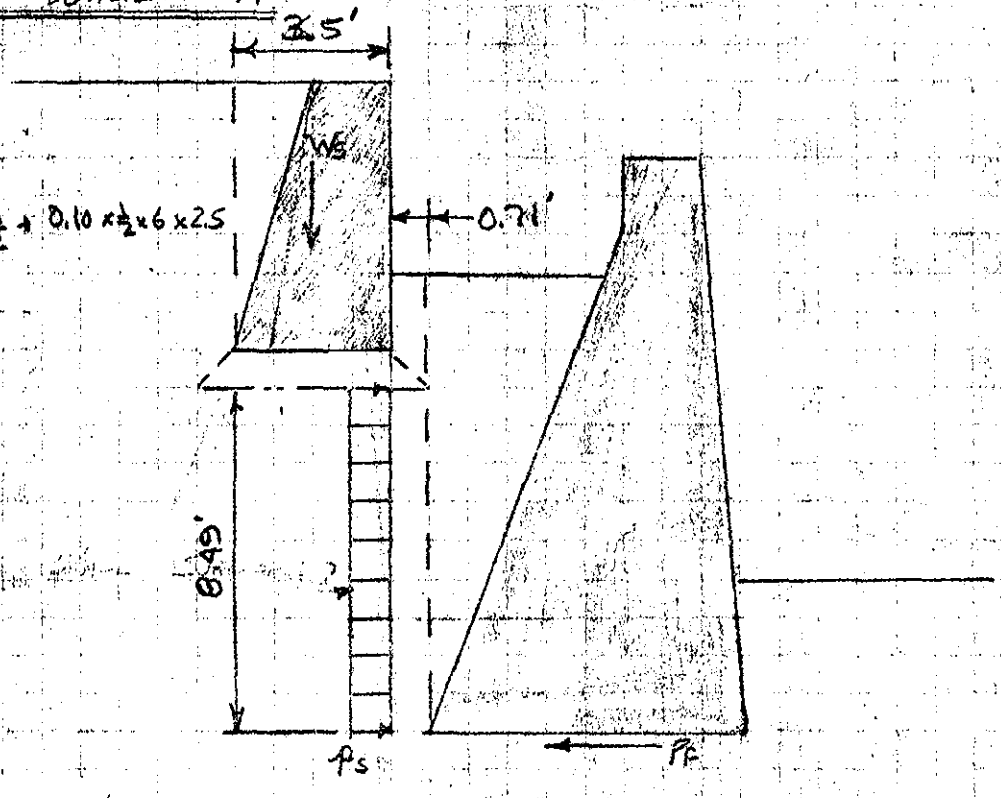
SECTION (B)(B)
SCALE: 1" = 6.0'

SUBJECT N. NASHUA

COMPUTATION CRIB SITE # 2 3

COMPUTED BY JF CHECKED BY DATE 6-8-77

STABILITY WALL 'A'



$W_S = 0.15(3.5+1.0)\frac{6}{2} + 0.10 \times \frac{1}{2} \times 6 \times 2.5$

$W_S = 2.78^K$

$w_S = \frac{2.78}{(3.5+2\times0.71)}$

$w_S = 0.57$ KSF

$P_S = 0.57 \times 0.33$

$P_S = 0.19$ KSF

LOADING CASES:

1. RAPID DRAW DOWN
2. NORMAL POOL W/ 2' TRUCK SURCHARGE

DESIGN CONSTANTS:

$\phi = 30°$
$\mu = 0.45$
$K_a = 0.33$
$K_P = 3.00$

$\gamma_{SAT} = 125.$ PCF
$\gamma_{SUB} = 62.5$ PCF
$\gamma_{DRY} = 100.$ PCF

$\gamma_{WAT} = 62.5$ PCF
$\gamma_{CONC} = 150$ PCF

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CORPS OF ENGINEERS, U.S. ARMY

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SUBJECT N. NASHUA

COMPUTATION CRIB SITE #2 4

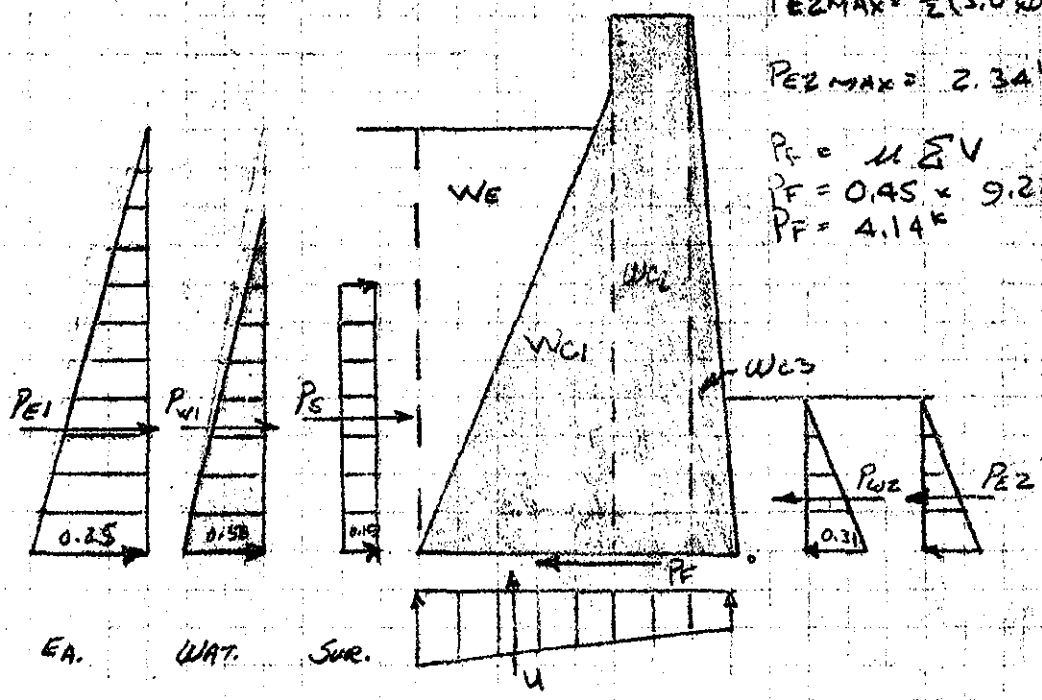
COMPUTED BY JF CHECKED BY DATE 6-8-77

LC-1 RAPID DRAW DOWN, DRAINS 50% Effective

$P_{EZMAX} = \frac{1}{2}(3.0 \times 0.0625)5^2$

$P_{EZ\,MAX} = 2.34^k$

$P_F = \mu \Sigma V$
$P_F = 0.45 \times 9.21$
$P_F = 4.14^k$



SEC.	FORCE COMPUTATION	VERT. (K) ↓	VERT. (K) ↑	HORIZ (K) →	HORIZ (K) ←	ARM (FT)	MOM (K·FT) ↷	MOM (K·FT) ↶
WC1	$0.15 \times \frac{1}{2} \times 5.29 \times 12.7$	5.04				3.90		19.67
WC2	$0.15 \times 1.0 \times 13.7$	2.06				1.64		3.38
WC3	$0.15 \times \frac{1}{2} \times 1.14 \times 13.7$	1.17				0.76		0.89
ΣWc		8.27						23.94
WE	$0.125 \times \frac{1}{2} \times 5.58 \times 12.2$	4.25				5.57		23.67
U	$\frac{1}{2} \times 7.43 (0.58 + 0.31)$		3.31			4.09	13.54	
PE1	$\frac{1}{2} \times 12.2 \times 0.25$			0.53		4.07	6.22	
PW1	$\frac{1}{2} \times 9.2 \times 0.58$			2.67		3.07	8.19	
PW2	$\frac{1}{2} \times 5.0 \times 0.31$				0.78	1.67		1.30
PS	8.49×0.19			1.61		4.25	6.83	
ΣH'				5.03			19.04	
PE2	} COMBINE TO RESIST ΣH'				0.89	1.67		1.49
PF	} USE FULL PF & MAKE UP DIFFERENCE W/ PE2				4.14	0.00		
Σ		8.52	3.31	5.03	5.03	—	33.48	49.90
		9.21	0	0	0		15	15.62

SUBJECT N. NASHUA

COMPUTATION CRIB SITE #2 5

COMPUTED BY JF CHECKED BY DATE 6-8-77

$\frac{\Sigma M}{\Sigma V} = \frac{15.62}{9.21} = 1.70'$ ∴ R IS OUTSIDE THE MID HALF BY 2" (.8%)

$BP = \frac{2 \times 9.21}{3 \times 1.70} = 3.61$ KSF

I'd say try 1:2 BACKSLOPE $P_{MAX} 0.45 \times 10.15 = 4.57$

SEC		VERT (1C) ↓	VERT (1C) ↑	HORIZ (1C) →	HORIZ (1C) ←	ARM (FT)	MOM (K-FT)	
WC1	0.15 × ½ × 6.35 × 12.7	6.05				4.26		25.75
WC2		2.06				1.64		3.38
WC3		1.17				0.76		0.89
ΣWC		9.28						30.02
WE	0.125 × ½ × 12.2 × 6.00	4.65				6.46		30.04
U	½ × 8.43 (0.58+0.31)		3.78				17.66	
PE1								
PW1								
PW2								
PS								
ΣH'				5.03			19.94	
PF	see pp 4 *				4.57	0.00	—	—
PE2					0.46	1.67		0.77
Σ		13.93	3.78			—	37.60	60.83
		10.15						23.23

$\frac{\Sigma M}{\Sigma V} = \frac{23.23}{10.15} = 2.29'$ ∴ R IS WITHIN THE MID-HALF

$BP = \frac{2 \times 10.15}{3 \times 2.29} = 2.95$ KSF

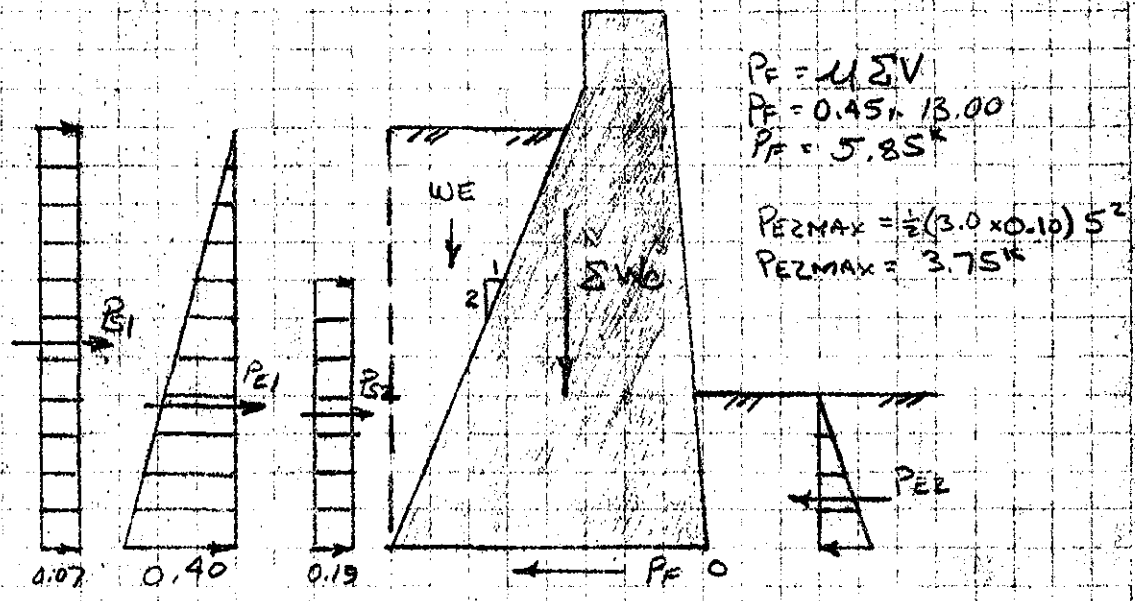
* NOT QUITE CORRECT TO USE PASSIVE w/ FRICTION BUT FOR THIS CASE IT'S SUITABLE, IF YOU ASK ME. IN SOME INSTANCES PASSIVE w/ FRICTION IS PERMISSIBLE.

SUBJECT N. NASHUA

COMPUTATION CRIB SITE #2 6

COMPUTED BY JF CHECKED BY DATE 6-8-77

LC-2 NORMAL CONDITION, DRY, W/ 2' TRAFFIC SURCHARGE



$P_F = \mu \Sigma V$
$P_F = 0.45 \times 13.00$
$P_F = 5.85^K$

$P_{EZMAX} = \frac{1}{2}(3.0 \times 0.10)\,5^2$
$P_{EZMAX} = 3.75^K$

SEC.	FORCE COMPUTATION	VERT. (K) ↓	VERT. (K) ↑	HORIZ. (K) →	HORIZ. (K) ←	ARM (FT)	MOM. (K-FT) →	MOM. (K-FT) ←
ΣWc		9.28						30.02
WE	$0.10 \times \frac{1}{2} \times 12.2 \times 6.1$	3.72				6.46		24.04
PE1	$\frac{1}{2} \times 12.2 \times 0.40$			2.44		4.07	9.93	
PS1	0.07×12.2			0.85		6.10	5.21	
PS2	0.19×8.49			1.61		4.25	6.86	
ΣH'				4.90			22.00	
PF PEZ	USE PF TO RESIST ΣH'			—	4.90 —	0.00		
Σ		13.00		4.90	4.90	—	22.00	54.06
		13.00		—	—			32.06

$\frac{\Sigma M}{\Sigma V} = \frac{32.06}{13.00} = 2.47'$ ∴ R IS OUTSIDE THE MID THIRD but within the MID HALF. (OUTSIDE MID-THIRD BY 4" OR 13%)

$BP = \frac{2 \times 13.00}{3 \times 2.47} = 3.51$ KSF

CLOSE ENOUGH FOR GOV'T WORK! IF VETOED SEE PP A1

SUBJECT N. NASHUA

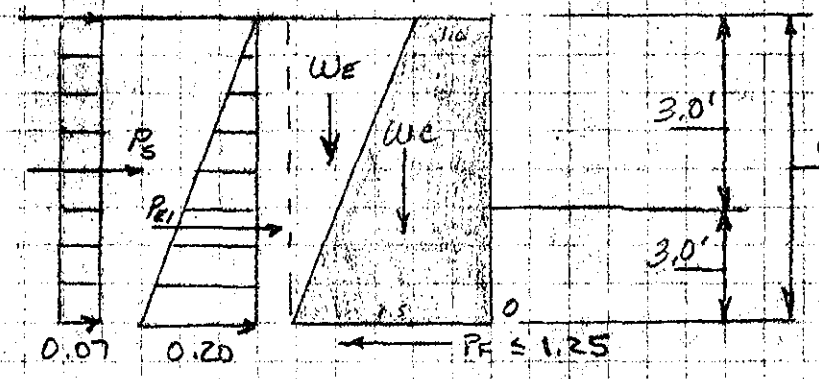
COMPUTATION CRIB SITE #2 7

COMPUTED BY JF CHECKED BY DATE 6-8-77

STABILITY WALL 'B'

LC2 - NORMAL CONDITION, DRY w/2' Traffic Surcharge (CRITICAL CASE)

NOTE: SEE PP A3 ON FROST PEN.



SEC.	FORCE COMPUTATION	VERT. (K) ↓	VERT. (K) ↑	HORIZ. (K) →	HORIZ. (K) ←	ARM (FT)	MOM. (K-FT) ↷	MOM. (K-FT) ↶
W_C	$0.15 \times \frac{1}{2} \times 6.0 (1.0 + 3.5)$	2.03				1.24		2.52
W_E	$0.10 \times \frac{1}{2} \times 6.0 \times 2.5$	0.75				2.67		2.00
P_{E1}	$\frac{1}{2} \times 6.0 \times 0.20$			0.60		2.0	1.20	
P_S	0.07×6.0			0.42		3.0	1.26	
$\Sigma H'$				1.02			2.46	
P_F					1.02	0.00	—	—
Σ		2.78		1.02	1.02	—	2.46	4.52
		2.78		0.00	0.00			2.06

$\frac{\Sigma M}{\Sigma V} = \frac{2.06}{2.78} = 0.74$ ∴ R IS OUTSIDE MID-HALF.

INCREASE BACKSLOPE TO 1:2 ⟸

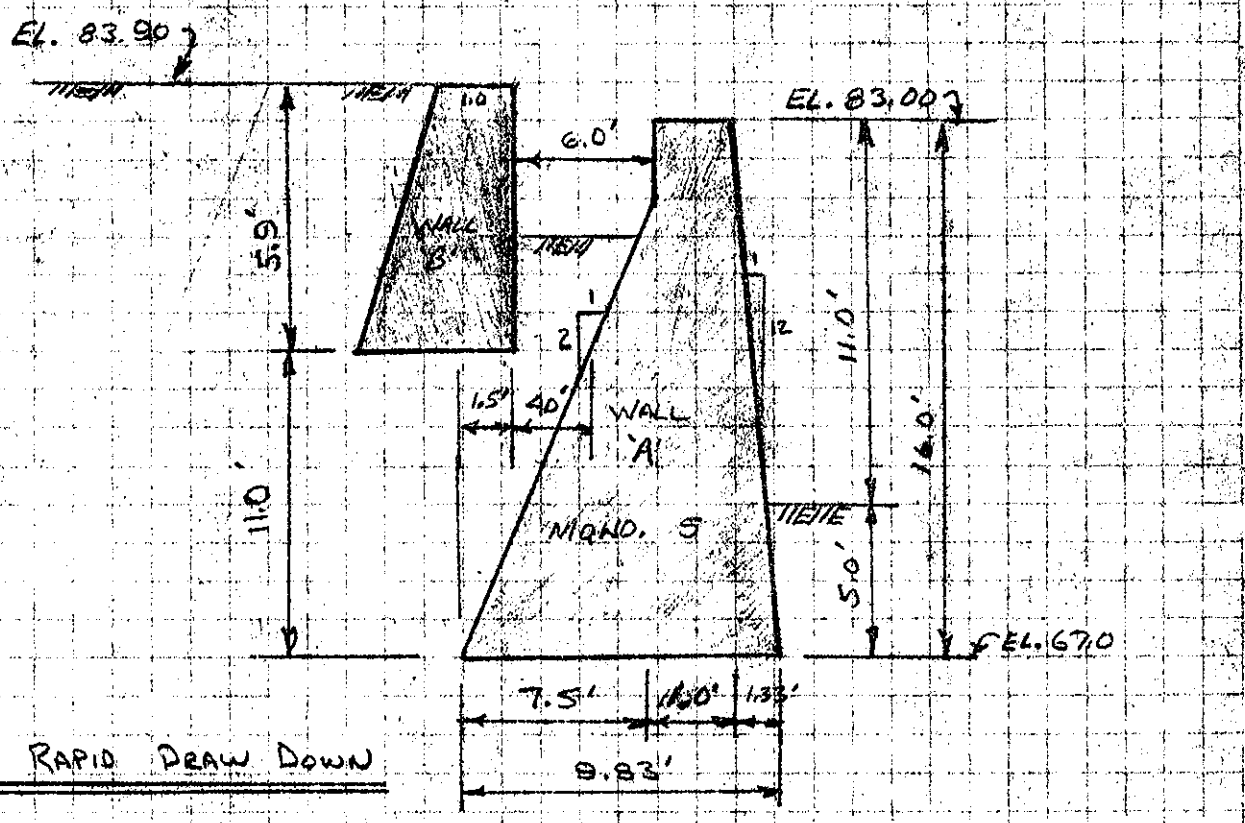
SEC.	FORCE COMP.	VERT. (K) ↓	VERT. (K) ↑	HORIZ. (K) →	HORIZ. (K) ←	ARM		
W_C	$0.15 \times \frac{1}{2} \times 6.0 (1.0 + 4.0)$	2.25				1.40		3.15
W_E	$0.10 \times \frac{1}{2} \times 6.0 \times 3.0$	0.90				3.00		2.70
P_{E1}								
P_S								
$\Sigma H'$				1.02			2.46	
P_F					1.02			
Σ		3.15			1.02	—	2.46	5.85
		3.15		1.02				3.39

$\frac{\Sigma M}{\Sigma V} = \frac{3.39}{3.15} = 1.08'$ ∴ R IS WITHIN THE MID-HALF

$BP = 2 \times 3.15 \div (3 \times 1.08) = 1.94$ KSF

SUBJECT N. NASHUA
COMPUTATION CRIB. SITE #2 8
COMPUTED BY VF CHECKED BY DATE 6-8-77

MONO. 5 - WALL 'A'



LC-1 RAPID DRAW DOWN

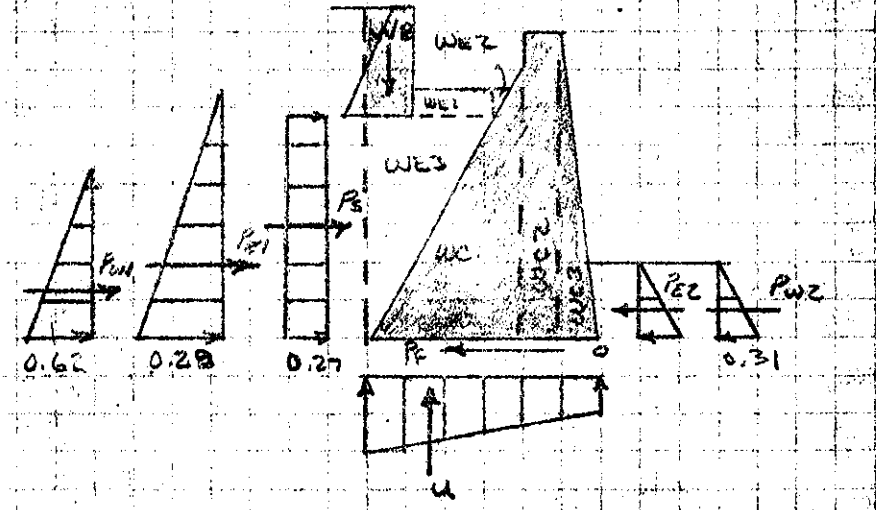
SURCHARGE FROM WALL 'B'

$$w_s = \frac{W}{A} = \frac{0.15 \times \frac{1}{2} \times 5.9 (11.0 + 4.0) + 0.125 \times \frac{1}{2} \times 3.0 \times 5.3}{4.0 \times 1.0}$$

$w_s = 0.83$ KSF

$p_s = 0.83 \times 0.33$

$p_s = 0.27$ KSF



SUBJECT N. NASHUA

COMPUTATION CRIB SITE No. 2 9

COMPUTED BY JF CHECKED BY DATE

LC-1 RAPID DRAW DOWN

SEC.	FORCE COMPUTATION	VERT. (K) ↓	VERT. (K) ↑	HORIZ. (K) →	HORIZ. (K) ←	ARM (FT)	MOM. (K-FT) ↷	MOM. (K-FT) ↶
W_{C1}	$0.15 \times \frac{1}{2} \times 15.0 \times 7.5$	8.44				4.83		40.77
W_{C2}	$0.15 \times 16.0 \times 1.0$	2.40				1.83		4.39
W_{C3}	$0.15 \times \frac{1}{2} \times 1.33 \times 16.0$	1.60				1.65		2.64
ΣW_C		12.44						47.80
W_{E1}	$0.125 \times 4.0 \times 3.9$	1.95				5.80		11.31
W_{E2}	$0.125 \times \frac{1}{2} \times 3.9 \times 2.0$	0.49				3.13		1.54
W_{E3}	$0.125 \times \frac{1}{2} \times 11.0 \times 5.5$	3.78				7.98		30.16
ΣW_E		6.22						43.01
W_B	0.83×1.5	1.25				9.08		11.35
U	$\frac{1}{2} \times 9.83 (0.62 + 0.31)$		4.57			5.46	24.96	
P_{W1}	$\frac{1}{2} \times 0.62 \times 10.0$			3.10		3.33	10.33	
P_{W2}	$\frac{1}{2} \times 0.31 \times 5.0$				0.78	1.67		1.30
P_C	0.27×8.49			2.29		4.25	9.72	
P_{E1}	$\frac{1}{2} \times 0.29 \times 14.0$			2.03		4.67	9.47	
$\Sigma H'$				6.64			28.22	
P_F					6.64	0.00		0.00
P_{E2}								
Σ		19.91	4.57	6.64	6.64		53.18	102.16
Σ		15.34		0.0	0.00			48.98

$P_F \leq 6.90$ K

$P_{E2} \leq 2.34$ K

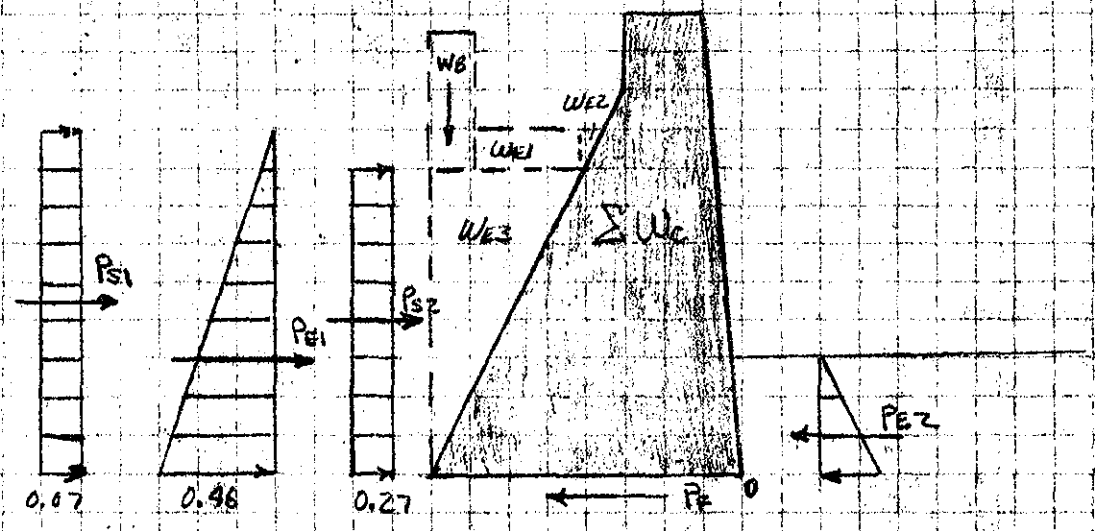
$\frac{\Sigma M}{\Sigma V} = \frac{48.98}{15.34} = 3.19'$ ∴ R is almost within the mid-third misses by 1" which isn't much to worry about OK It is w/in the mid-half. s.

$BP = \frac{2 \times 15.34}{3 \times 3.19} = 3.21$ KSF

SUBJECT No. NASHUA
COMPUTATION CRIB SITE #2 (10)
COMPUTED BY JF CHECKED BY DATE 6-9-77

LC-2 NORMAL CONDITION w/ 2' TRAFFIC SURCHARGE

WALL 'A'



SEC.	FORCE COMPUTATION	VERT. (K) ↓	VERT. (K) ↑	HORIZ. (K) →	HORIZ. (K) ←	ARM (FT)	MOM. (K-FT) ↷	MOM. (K-FT) ↶
ΣWc	see PP 9	12.44						47.60
ΣWE	0.8 x Results PP 9	4.98						34.41
WB	see PP 9	1.25				9.08		11.35
PE1	½ x 14.0 x 0.46			3.22		4.67	15.04	
PS1	0.07 x 14.0			0.98		7.00	6.86	
PS2	0.27 x 8.49			2.29		4.25	9.72	
ΣH'				6.49			31.62	
PF	~~(0.45 x 18.67 = 8.40)~~				6.49	0.00		
PE2	≤ [½ (3.0 x 0.10) 5² = 3.75)	—	—	—	—	—	—	—
Σ		18.67	0.00	6.49	6.49	—	31.62	93.56
		18.67		0.00				61.94

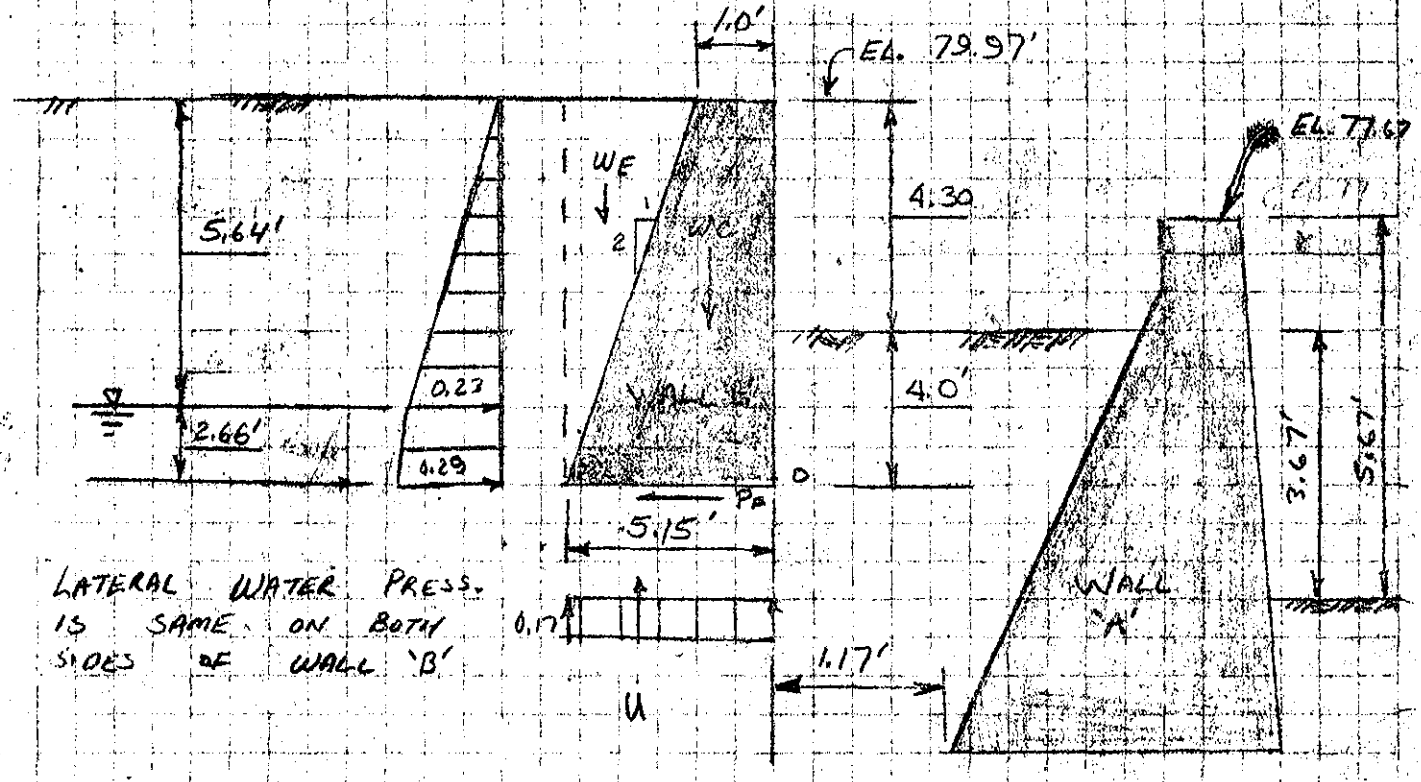
$\frac{\Sigma M}{\Sigma V} = \frac{61.94}{18.67} = 3.32'$ ∴ R is indeed w/in the mid. third. e = 1.60

$BP_{MAX} = \frac{18.67}{9.83}\left(1 + \frac{6 \times 1.60}{9.83}\right) = 3.75$ KSF

SUBJECT N. NASHUA
COMPUTATION CRIB SITE #2 (11)
COMPUTED BY JF CHECKED BY DATE 6-9-77

TRY WALL 'B' MONO. 2

LC-1 RAPID DRAW DOWN



LATERAL WATER PRESS. IS SAME ON BOTH SIDES OF WALL 'B'

SEC.	FORCE COMPUTATION	VERT. (K) ↓	VERT. (K) ↑	HORIZ. (K) →	HORIZ. (K) ←	ARM (FT)	MOM. (K-FT) ↷	MOM. (K-FT) ↶
Wc	0.15 × ½ × 8.30 (5.15+1.0)	3.83				1.77		6.78
WE	0.125 × 4.15 × 8.30	4.31				3.77		16.23
U	0.17 × 5.15		0.88			2.58	2.27	
PE1	½ × 5.64 × 0.23			0.65		4.54	2.95	
PE2	½ × 2.66 (0.23+0.29)			0.69		1.28	0.88	
ΣH'				1.34			3.83	
PF	≤ 0.45 × 7.26 = 3.27				1.39			
Σ		8.14	0.88	1.34	1.34	—	6.10	23.01
		7.26		0.00				16.91

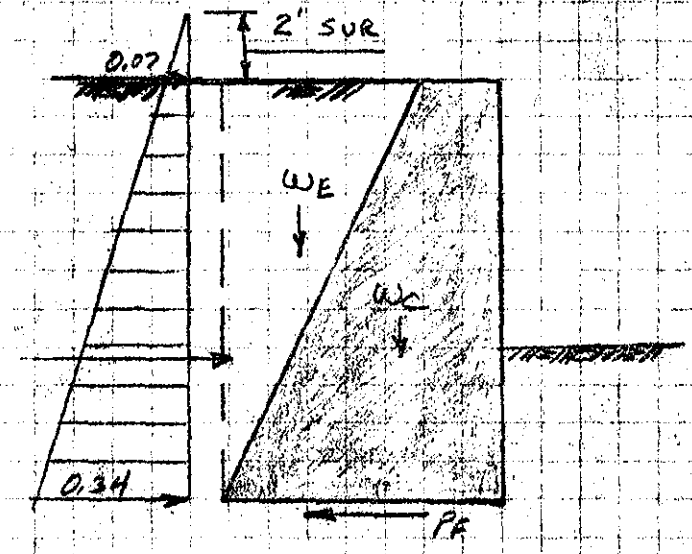
$\frac{\Sigma M}{\Sigma V} = \frac{16.91}{7.26} = 2.33'$ ∴ R IS WITHIN THE MID-THIRD

$e = 0.25'$

$BP_{MAX} = \frac{7.26}{5.15}\left(1 + \frac{6 \times 0.25}{5.15}\right) = 1.81$ KSF

SUBJECT No Nashua
COMPUTATION Crib Site #2 (12)
COMPUTED BY JF CHECKED BY DATE 6-9-77

LC-2 NORMAL CONDITION, DRY EARTH, 2' TRAFFIC SURCHARGE



SEC.	FORCE COMPUTATION	VERT. (K) ↓	VERT. (K) ↑	HORIZ. (K) →	HORIZ. (K) ←	ARM (FT)	MOM. (K-FT) ↷	MOM. (K-FT) ↶
W_C		3.83				1.77		6.78
W_E	$0.10 \times \frac{1}{2} \times 4.15 \times 8.30$	3.44				3.77		12.99
P_E	$\frac{1}{2} \times 8.3(0.07 + 0.34)$			1.70		3.24	5.51	
P_F	$\leq (0.45 \times 7.27 = 3.27)$				1.70			
Σ		7.27	0.00	1.70	1.70		5.51	19.77
		7.27		0.00				14.26

$\frac{\Sigma M}{\Sigma V} = \frac{14.26}{7.27} = 1.96'$ $\therefore$ R IS WITHIN THE MID-3RD
$e = 0.62'$

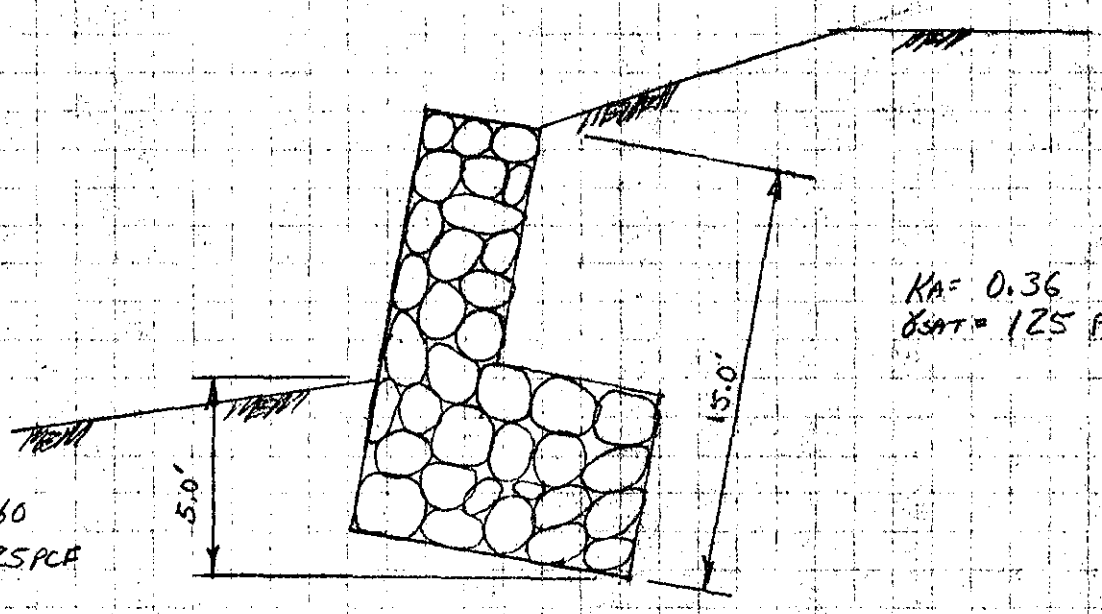
$P_{MAX} = \frac{7.27}{5.15}\left(1 + \frac{6 \times 0.62}{5.15}\right) = 2.42$ KSF

SUBJECT N. NASHUA

COMPUTATION AREA 'A' 24

COMPUTED BY JF CHECKED BY DATE 6/28/77

AREA "A" - GABION WALL



$K_A = 0.36$
$\gamma_{SAT} = 125$ PCF

$K_P = 1.60$
$\gamma_{SAT} = 125$ PCF

TYPICAL - SECTION
N.T.S.

SUBJECT No. NASHUA

COMPUTATION AREA 'A' 25

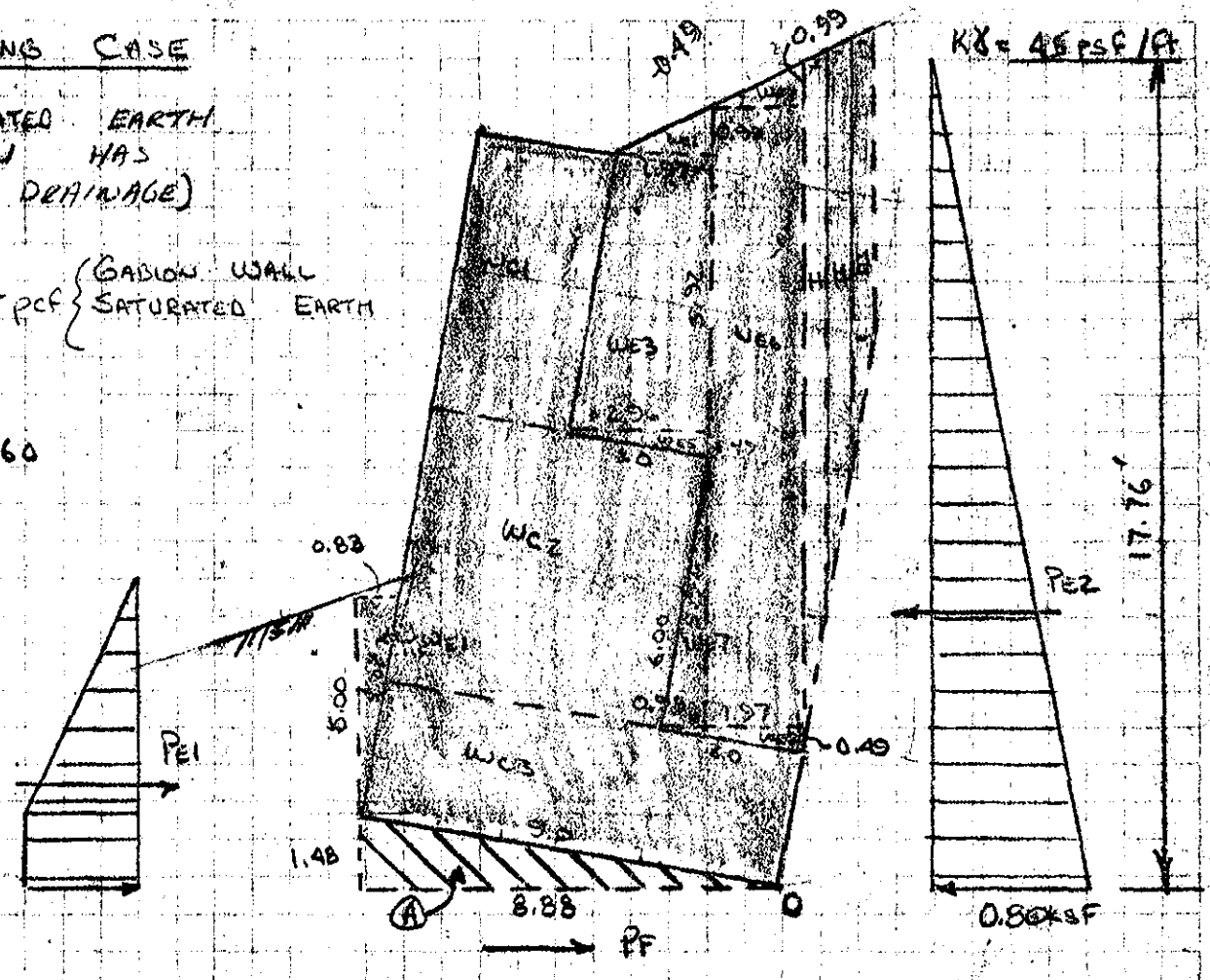
COMPUTED BY JF CHECKED BY DATE 6/28/77

LOADING CASE

SATURATED EARTH
(GABION HAS
FULL DRAINAGE)

$\gamma = 125$ pcf { GABION WALL / SATURATED EARTH

$K_P = 1.60$



$W_A = 0.125 \times \frac{1}{2} \times 1.48 \times 8.88$

$W_A = 0.82^K$

$P_{E1} \leq \frac{1}{2}(1.60 \times 0.125 \times 5.0)(1.48 + 6.48)$

$P_{E1} \leq 3.98^K$

SUBJECT N. NASHUA

COMPUTATION Area 'A' 26

COMPUTED BY JF CHECKED BY DATE 6-28-77

SEC.	FORCE COMPUTATION	VERT. (K) + ↓	HORZ. (K) ← +	ARM (FT)	MOM (K-FT)
W_{C1}	$0.125 \times 3.0 \times 6.0$	2.25		4.19	9.43
W_{C2}	$0.125 \times 6.0 \times 6.0$	4.50		4.92	22.13
W_{C3}	$0.125 \times 3.0 \times 6.0$	2.25		5.40	12.15
ΣW_C		9.00			43.71
W_{E1}	$0.125 \times \frac{1}{2} \times 0.83 \times 5.00$	0.26		8.60	2.24
W_{E2}	$0.125 \times \frac{1}{2} \times 1.97 \times 0.99$	0.12		2.14	0.26
W_{E3}	$0.125 \times \frac{1}{2} \times 5.92 (1.97 + 2.96)$	1.82		2.73	4.97
W_{E4}	$0.125 \times \frac{1}{2} \times 1.97 \times 0.99$	0.12		0.17	0.02
W_{E5}	$0.125 \times \frac{1}{2} \times 2.96 \times 0.49$	0.09		2.47	0.22
W_{E6}	$0.125 \times 1.97 \times 13.32$	3.28		0.50	1.64
W_{E7}	$0.125 \times \frac{1}{2} \times 0.99 \times 5.92$	0.37		1.81	0.67
W_{E8}	$0.125 \times \frac{1}{2} \times 2.96 \times 0.49$	0.09		0.50	0.05
ΣW_E		6.15			10.07
P_{E1}	$\frac{1}{2} \times 17.76 \times 1.24$		11.10	5.92	42.06
P_F	$\leq 0.45(0.82 + 15.15) = 7.19$		- 7.19	0.00	0.00
P_{E1}	≤ 3.98		-0.00	2.25	-0.00
Σ		15.15	0.00		85.84

$\frac{\Sigma M}{\Sigma V} = \frac{85.84}{15.15} = 6.33'$ (0.71 L) ∴ R IS INSIDE MID-HALF.

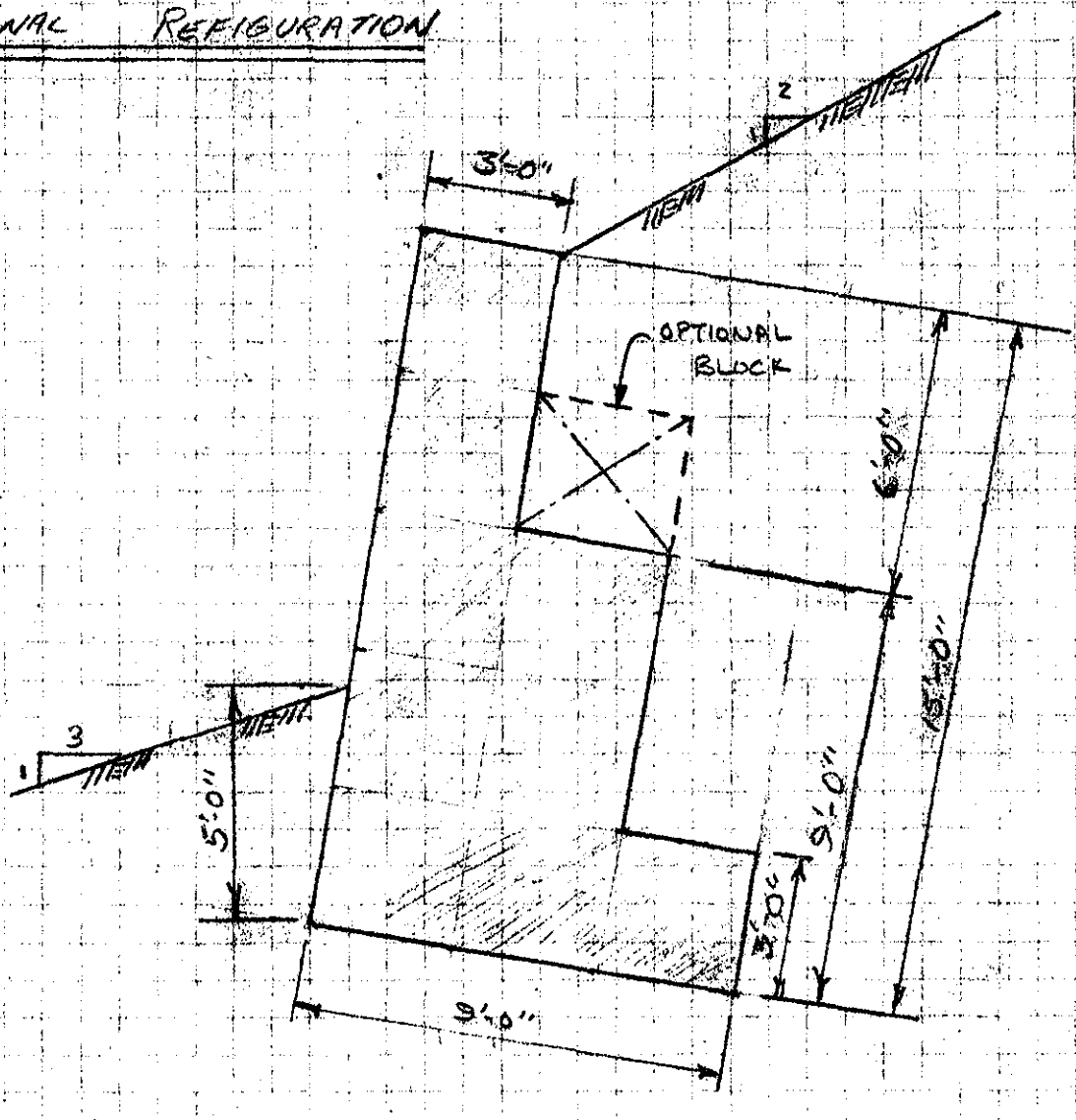
$B_P = \frac{2 \times 15.15}{3(8.88 - 6.33)} = 3.96$ KSF OK

SUBJECT N. NASHUA

COMPUTATION AREA 'A' 28

COMPUTED BY JF CHECKED BY DATE 6/29/77

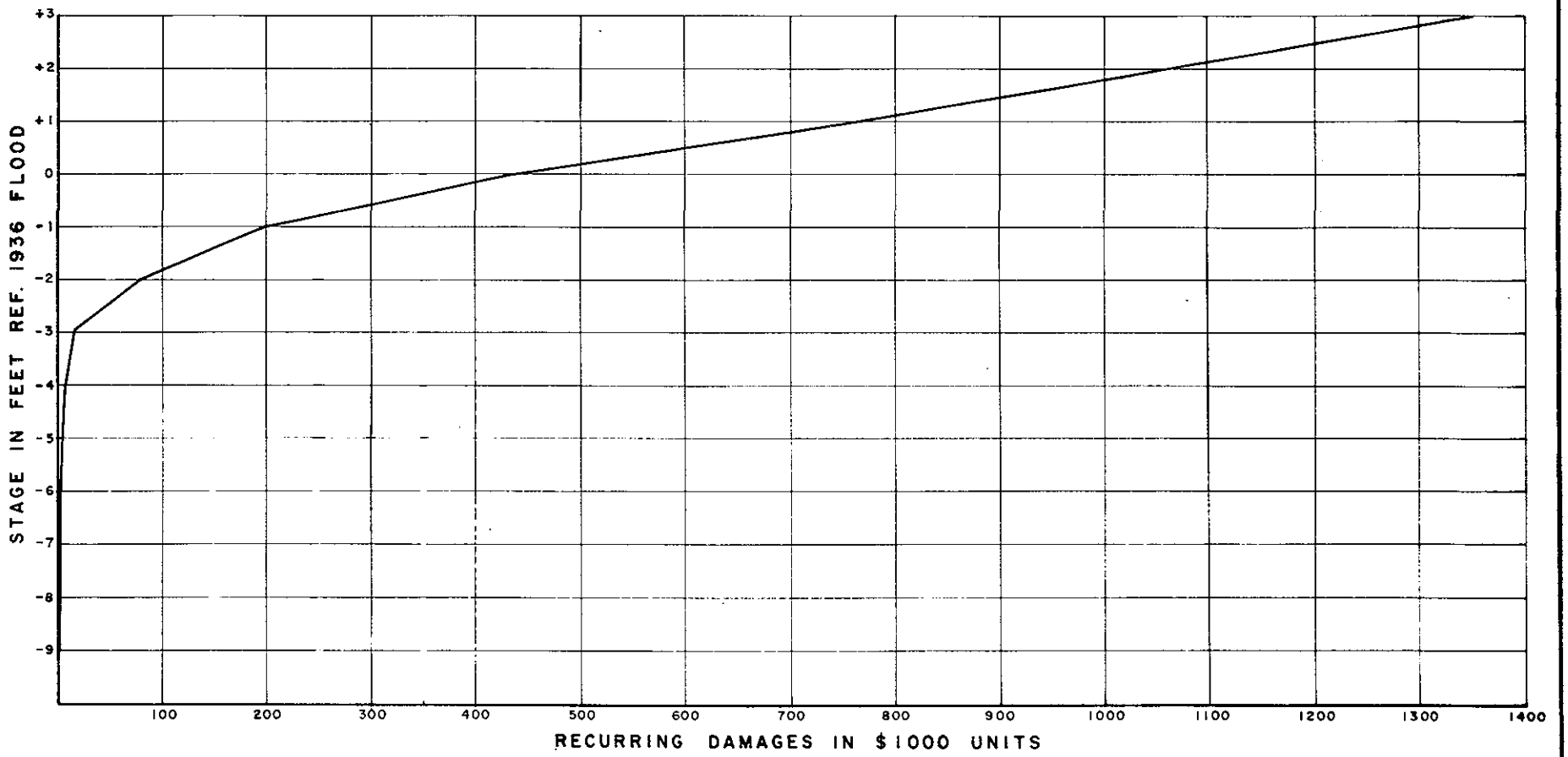
FINAL REFIGURATION



GABION WALL SECTION
SCALE: 1/4" = 1'-0"

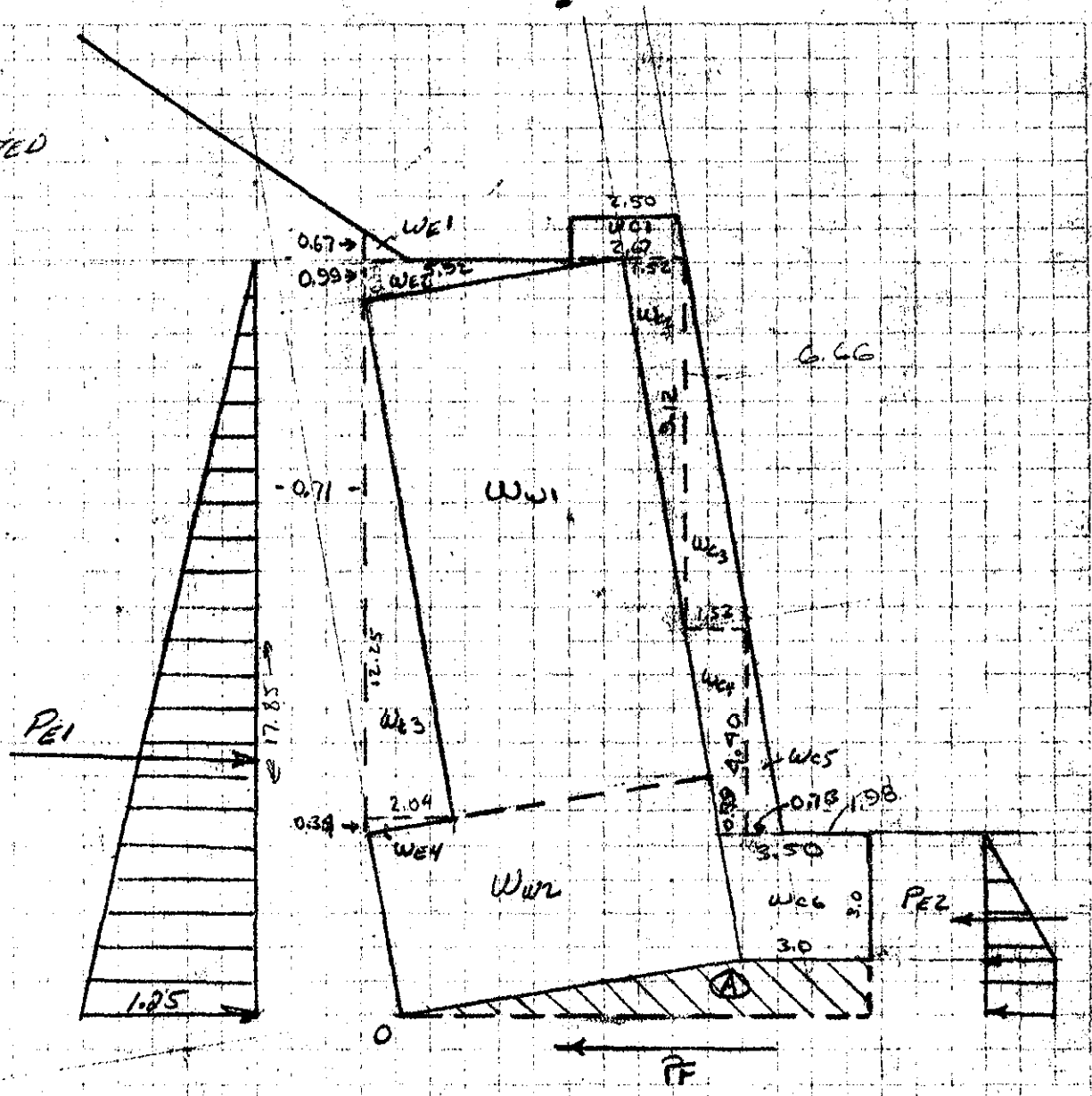
STAGE DAMAGE CURVE

NORTH NASHUA RIVER BASIN
ZONE 16
SHELDON STREET BRIDGE (D/S)
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL



SUBJECT No. NASHUA
COMPUTATION CRIB SITE No. 7 — 36
COMPUTED BY JF — CHECKED BY — DATE 6/28/77

LC-2
SATURATED
EARTH



$A_{(A)} = \frac{1}{2} \times 1.32 \times (10.89 + 7.89)$

$A_{(A)} = 12.40\ ft^2$

$W_{(A)} = 12.40 \times 0.125$

$W_{(A)} = 1.55^K$ ← USE TO COMPUTE FRICT.

I.E.

$P_F = \mu (\Sigma V + 1.55)$

$P_{E2} = \frac{1}{2}(3.0 \times 30 \times 0.125)(1.32 + 4.32)$

$P_{E2} = 3.17^K$

SUBJECT No. NASHUA

COMPUTATION CRIB SITE No. 7 37

COMPUTED BY VE CHECKED BY DATE 6-28-77

LC-2 SATURATED EARTH ONLY

SEC.	FORCE COMPUTATION	VERT. ↓+	HORIZ. →+	ARM	MOM. ↺+
W_{W1}	$0.125 \times 12.42 \times 6.0$	9.32	4.69		43.73
W_{W2}	$0.125 \times 4.33 \times 8.0$	4.33	4.30		18.63
ΣW_W		13.65			62.36
W_{E1}	$0.15 \times \frac{1}{2} \times 1.0(2.50+2.67)$	0.39		5.28	2.06
W_{E2}	$0.15 \times \frac{1}{2} \times 1.52 \times 9.12$	1.04		6.15	6.40
W_{C3}	$0.15 \times \frac{1}{2} \times 1.52 \times 9.12$	1.04		7.17	7.45
W_{C4}	$0.15 \times \frac{1}{2} \times 4.40(0.79+1.52)$	0.76		7.58	5.76
W_{C5}	$0.15 \times \frac{1}{2} \times 0.73 \times 4.40$	0.24		8.42	2.02
W_{C6}	$0.15 \times \frac{1}{2}(3.0)(3.0+3.50)$	1.46		9.26	13.52
ΣW_C		4.84			37.21
W_{E1}	$0.125 \times \frac{1}{2} \times 0.67 \times 1.0$	0.04		0.38	-0.02
W_{E2}	$0.125 \times \frac{1}{2} \times 5.92 \times 0.99$	0.37		1.26	0.47
W_{E3}	$0.125 \times \frac{1}{2} \times 12.25 \times 2.04$	1.56		0.03	-0.05
W_{E4}	$0.125 \times \frac{1}{2} \times 2.04 \times 0.34$	0.04		0.03	0.00
ΣW_E		2.01			0.40
P_{E1}	$\frac{1}{2} \times 17.85 \times 1.25$		11.16	5.95	66.40
P_F	$\leftarrow 0.45(20.50+1.55) = 9.92$		-9.92	0.00	0.00
P_{E2}	$\leftarrow 3.17$		-1.24	1.54	-1.91
ΣV		20.50	0.00		164.46

$\frac{\Sigma M}{\Sigma V} = \frac{164.46}{20.50} = 8.02'$ $(0.74L)$

R_1 IS WITHIN THE MID-HALF. (IT SHOULD BE WITHIN THE MID THIRD)

$BP = \frac{20.50 \times 2}{3(10.83 - 8.02)}$

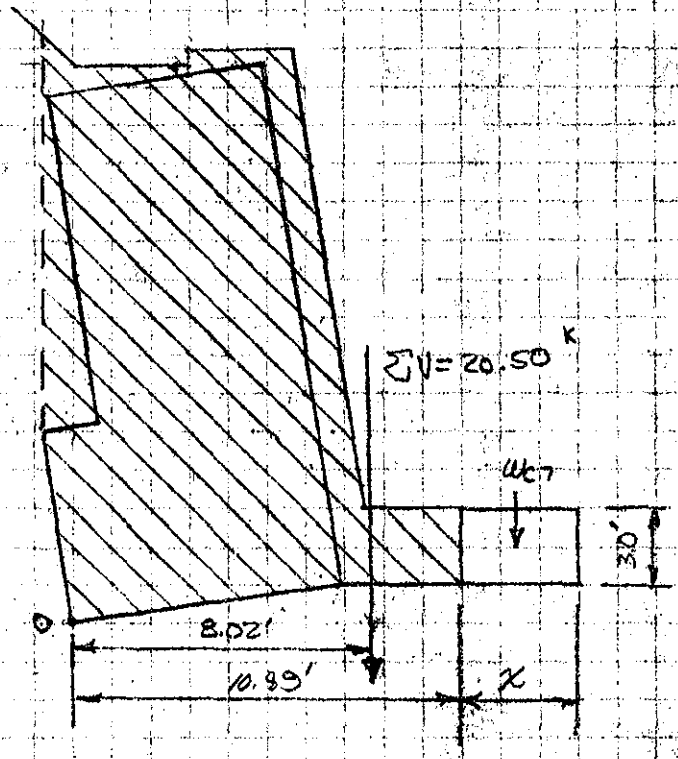
$BP = 4.76$ KSF

PROVIDE WEEP HOLES

SUBJECT N. NASHUA

COMPUTATION CRIB SITE No. 7 374

COMPUTED BY JF CHECKED BY DATE 6/28/77



$\Sigma V = 20.50 + 3.0x\,(0.15)$

$\Sigma V = 0.45x + 20.50$

$\Sigma M = 164.46 + 0.45x\left(10.89 + \frac{x}{2}\right)$

$\Sigma M = 0.23x^2 + 4.90x + 164.46$

$\frac{\Sigma M}{\Sigma V\,(x + 10.89)} = 0.67$

$\Sigma M = 0.67(x + 10.89)(0.45x + 20.50)$

$0.23x^2 + 4.90x + 164.46 = 0.67(0.45x^2 + 25.40x + 223.25)$

$0.23x^2 + 4.90x + 164.46 = 0.30x^2 + 17.02x + 149.57$

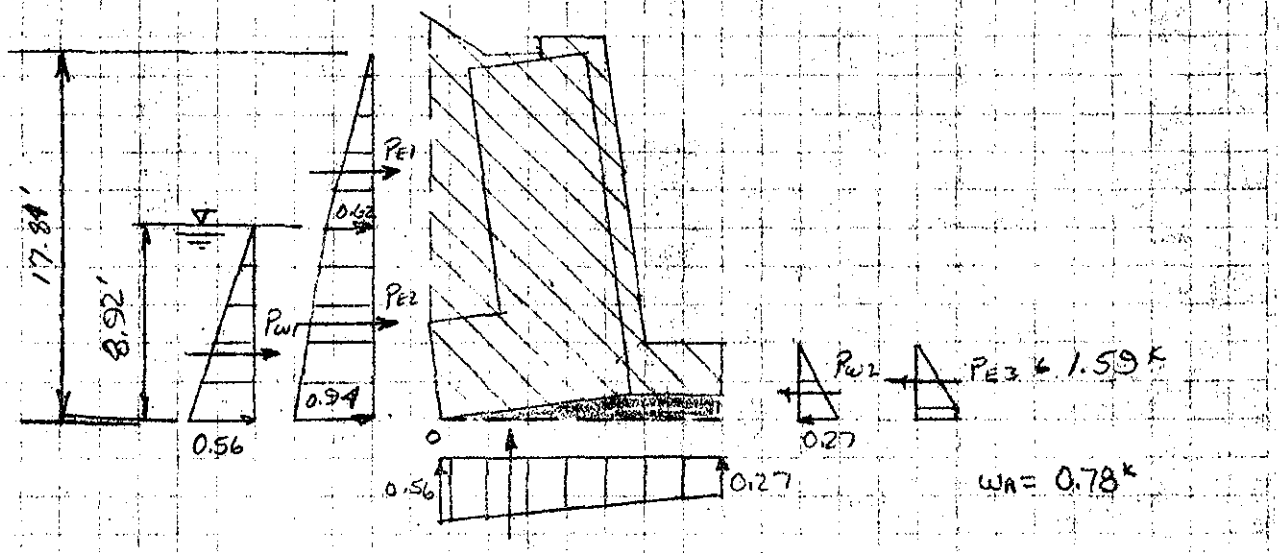
$0 = 0.07x^2 + 12.12x - 14.89$

$x^2 + 173.14x - 212.71 = 0$

$x = 1.22$

SUBJECT N. NASHUA
COMPUTATION CRIB SITE No. 7 38
COMPUTED BY JF CHECKED BY DATE 6-28-77

LC-L GRID DRAWDOWN (50% DRAIN EFFICIENCY)



SEC.	FORCE COMPUTATION	VERT. (K) ↓ +	HORIZ. (K) → +	ARM (FT)	MOM (K') ↷ +
ΣWw		13.65			62.36
ΣWc		4.84			37.21
ΣWE		2.01			0.40
U	½ × 10.89 (0.56 + 0.27)	- 4.52		4.81	-21.74
Pw1	½ × 0.56 × 8.92		2.50	2.97	7.43
Pw2	½ × 0.27 × 4.32		- 0.58	1.44	- 0.84
Pe1	½ × 8.92 × 0.62		2.77	11.89	32.94
Pe2	½ × 8.92 (0.62 + 0.94)		6.96	4.16	28.92
ΣH'			11.65		68.45
Pf (1)	← 0.45 (15.98 + 0.78) = 7.54 } 9.13 K (1)		-10.06		
Pe3	← 1.59		-1.59	1.54	- 2.45
Σ		15.98	0.00		144.23

1. U_{AVG} = (11.65 - 1.59) K (15.98 + 0.78) = 0.60 a bit high but CONTINUE

2. $\frac{\Sigma M}{\Sigma V} = \frac{144.23}{15.98} = 9.03$ (0.83 L) R IS OUTSIDE MID HALF

3. $BP = \frac{2 \times 15.98}{3(10.89 - 9.03)} = 5.73$ KSF

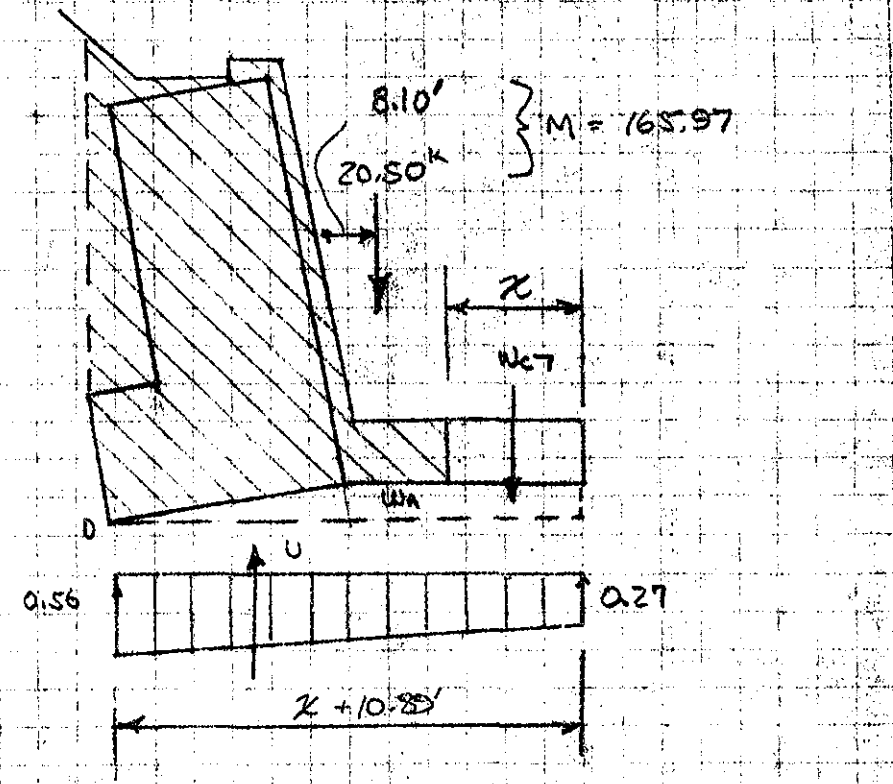
SUBJECT N. NASHUA
COMPUTATION CRIB SITE No. 7 39
COMPUTED BY JF CHECKED BY DATE 6/28/77

$W_A = 0.78 + 0.0625 \times 1.32\,x$

$W_A = 0.08\,x + 0.78$

$\Sigma H' = 11.65^K$

$U_{REQ} = \dfrac{\Sigma H' - P_{EZ}}{\Sigma V + W_A}$



$\Sigma U = 20.50 - U + W_{c7}$
$\Sigma U = 20.50 - \frac{1}{2}(x+10.89)(0.83) + 0.15 \times 3.0\,x$
$\Sigma U = 20.50 - 0.42x - 4.52 + 0.45x$
$\Sigma V = 0.03x + 15.98$

For $W_A + \Sigma V$ To RESIST $\Sigma H'$

$$x = \frac{10.06 - 16.76}{0.11}$$

U_R	0.45	0.50	0.55	0.60	
$x_{REQ'D}$	50.87	30.55	13.92	0.06	(FT)

x

$\Sigma M = M + M_{c7} + M_U$
$\Sigma M = 165.97 + 0.45\,x(10.89 + \frac{x}{2}) - \frac{(x+10.89)^2}{6}(1.10)$
$\Sigma M = 165.97 + 0.23x^2 + 4.90x - 0.18x^2 - 3.99x - 21.74$
$\Sigma M = 0.05x^2 + 0.91x + 144.23$

SUBJECT N. NASHUA
COMPUTATION CRIB SITE No.7 40
COMPUTED BY JF CHECKED BY DATE 6/28/77

$\frac{\Sigma M}{\Sigma V} = 0.75(x+10.89)$

$\Sigma M = 0.75(x+10.89)(0.03x+15.98)$

$0.05x^2 + 0.91x + 144.73 = 0.02x^2 + 12.23x + 130.52$

$0.03x^2 - 11.32x + 13.71 = 0$

$x^2 - 377.33 + 457 = 0$

$x = 1.21'$

if $x = 1.21$ $\mu_{REQ'D} = 0.60$

SEC	FORCE COMPUTATION	VERT (K) ↓	HORIZ. →+	ARM (FT)	MOM (K') ↷+
ΣW_W		13.65			62.63
ΣW_C		4.84			37.21
W_{C7}	$0.15 \times 3.0 \times 1.21$	0.54		11.50	6.21
ΣW_E		2.01			0.40
U	$\frac{1}{2} \times (10.89 + 1.21)(0.56 + 0.27)$	-5.02			-26.84
$\Sigma H'$			11.65		68.45
T_{EB}			-1.59	1.54	-2.54
PF	$\mu_{REQ} = 0.60$		-10.06	0.00	0.00
Σ		16.02	0.00		145.52

$\frac{\Sigma M}{\Sigma V} = \frac{145.52}{16.02} = 9.08'$ $(0.75L)$ R is WITHIN THE MID HALF 145.40

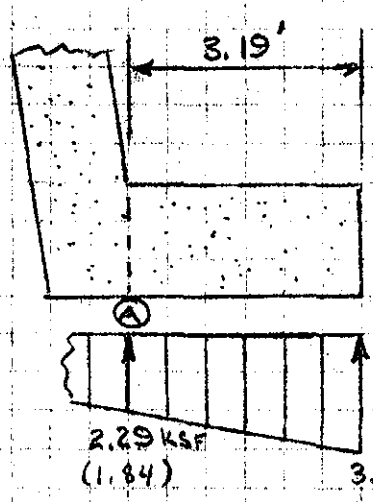
$BP = \frac{2 \times 16.02}{3 \times (12.10 - 9.08)} = 3.54$ KSF

SUBJECT N. NASHUA

COMPUTATION CRIB SIZE NO. 7 41

COMPUTED BY VE CHECKED BY DATE 6/28/77

FACE DESIGN



$W_c = 0.45$ KSF

$M_A = \frac{3.19^2}{6}(2 \times 3.09 + 1.84)$ ← ASSUME MOMENT AT THE STEM @ THE TOP OF THE BASE. DESIGN STEM USING MA.

$M_A = 13.60^{K'}$

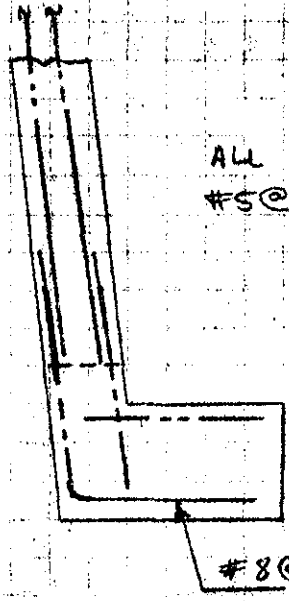
$d_{REQ} = \left(\frac{13.60}{.152}\right)^{1/2} = 9.46"$

$d_{PROV.} = 14.5"$ OK

$A_{SREQ} = \frac{13.60}{1.44 \times 14.5}$

$A_{SREQ'D} = 0.65$ ← #8 @ 12"

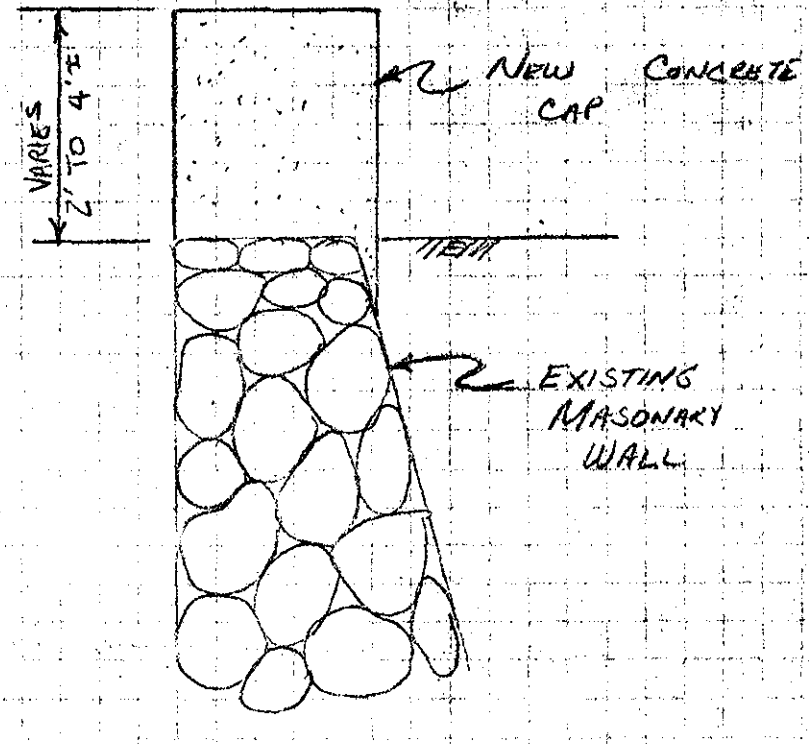
PROVIDE 4"Ø WEEP HOLES 4'-0" C.C. E.W.



SUBJECT No NASHUA

COMPUTATION AREA 'N' 42

COMPUTED BY JF CHECKED BY DATE 7-14-77



RIVERSIDE

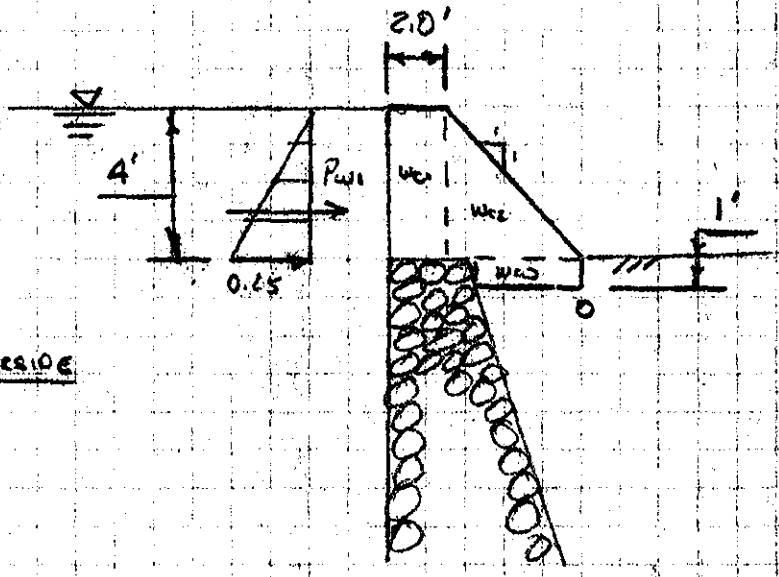
TYP. SECTION
N.T.S.

1. ASSUME EXISTING WALL WILL SUPPORT NEW CAP.
2. DESIGN CAP AS IF IT ACTS INDEPENDENTLY FROM THE EXISTING WALL.

SUBJECT N. NASHUA
COMPUTATION AREA N 44A
COMPUTED BY JF CHECKED BY DATE 7-14-77

AREA N

CAP ON EXISTING MASONARY WALL ON SOUTH SIDE TO MATCH ELEVATION OF EXISTING NORTH FLOOD WALL.



ASSUME CONC. SECTION ON WALL ACTS AS A GRAVITY WALL AND THE EXISTING WALL WILL REMAIN IN FACT.

UPLIFT

4' RIVERSIDE
0' LANDSIDE

SECT.	FORCE COMPUTATION	VERT. (K) ↓+	HOR. (K) →+	ARM (FT)	MOM. (K') ↺+
Wc1	0.15 × 2 × 4	1.20		5.00	6.00
Wc2	0.15 × ½ × 4²	1.20		2.66	3.20
Wc3	0.15 × 1.0 × 3	0.45		3.00	1.35
U	½ × 0.25 × 6	-0.75		4.00	-3.00
Pw	½ × 4 × 0.25		0.50	1.33	-0.67
PF			-0.50		
		2.10	0.00		6.88

$\frac{\Sigma M}{\Sigma V} = \frac{6.88}{2.10} = 3.28 \quad (0.55L)$ ∴ R IS WITHIN THE MID-HALF OK

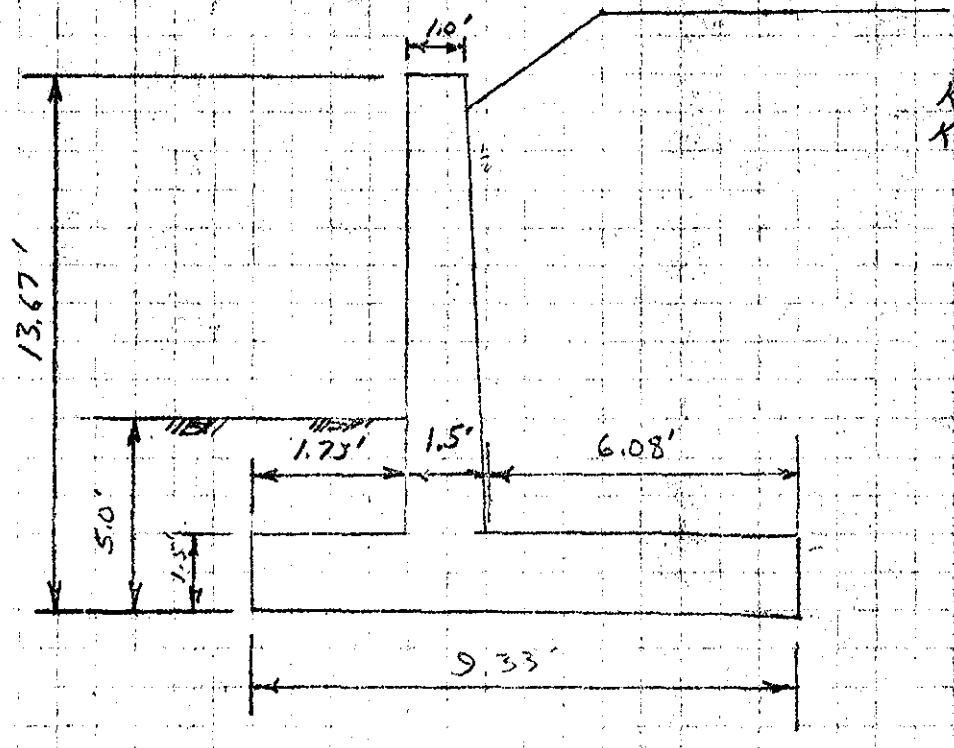
$\frac{P_w}{\Sigma V} = \frac{0.50}{2.10} = 0.24 < 0.45$ ∴ OK

$BP = \frac{2.10}{6}\left(1 + \frac{6 \times 0.28}{6}\right) = 0.45$ KSF

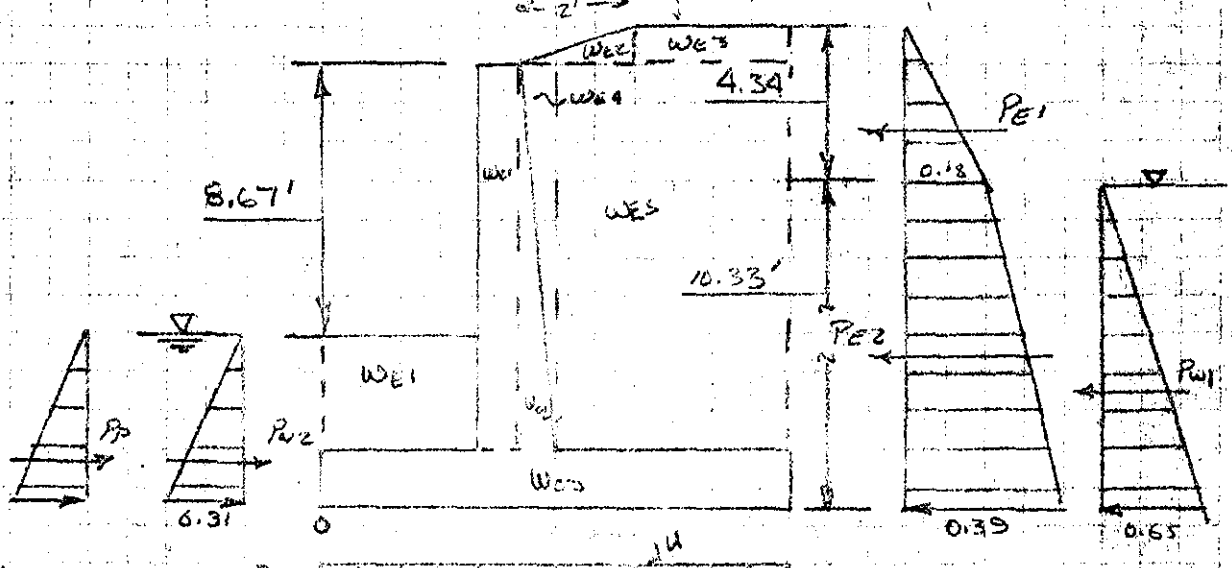
SUBJECT N. NASHUA
COMPUTATION CANT. WALL 45
COMPUTED BY JF CHECKED BY DATE

Check A CANTILEVER WALL FOR 13.67' Ht.

(CCIO SITE #5 & #6 TYPICAL DESIGN)

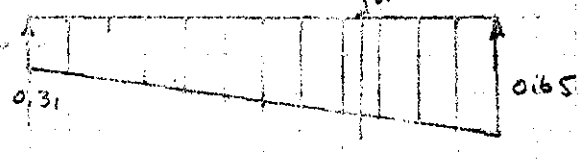


LC-1 - RAPID DRAWDOWN CONDITION



$P_{pb} = \frac{1}{2}(3.0 \times 0.0625 \times 5.0^2)$

$P_{pb} = 2.34^{k}$



SUBJECT N. NASHUA

COMPUTATION CANT. WALL 46

COMPUTED BY JF CHECKED BY DATE 9-26-77

LC-1 -- RAPID DRAW DOWN

SEC.	FORCE COMPUTATION	VERT. ↑ (K)	HORIZ. →+ (K)	ARM (FT)	MOM ↺ (KFT)
W_{C1}	$0.15 \times 1.0 \times 12.17$	1.83		2.25	4.12
W_{C2}	$0.15 \times \frac{1}{2} \times 0.5 \times 12.17$	0.46		2.92	1.34
W_{C3}	$0.15 \times 1.5 \times 9.33$	2.08		4.67	9.70
W_{E1}	$0.125 \times 3.5 \times 1.75$	0.77		0.88	0.67
W_{E2}	$0.125 \times \frac{1}{2} \times 1.0 \times 2.0$	0.13		4.08	0.53
W_{E3}	$0.125 \times 1.0 \times 4.08$	0.51		7.29	3.72
W_{E4}	$0.125 \times \frac{1}{2} \times 0.5 \times 12.17$	0.38		3.08	1.17
W_{ES}	$0.125 \times 6.08 \times 12.17$	9.25		6.29	58.18
U	$\frac{1}{2} \times 9.33 (0.31 + 0.65)$	-4.48		5.21	-23.36
P_{E1}	$\frac{1}{2} \times 4.34 \times 0.18$		-0.39	11.78	-4.59
P_{E2}	$\frac{1}{2} \times 10.33 (0.18 + 0.39)$		-2.94	4.53	-13.32
P_{W1}	$\frac{1}{2} \times 10.33 \times 0.65$		-3.36	3.44	-11.57
P_{W2}	$\frac{1}{2} \times 5.0 \times 0.31$		0.78	1.67	1.30
$\Sigma H'$			5.91		-28.18
P_{US} P_R	$\leq (0.54 \times 10.33 = 5.91)$		5.91	0.00	0.00
Σ		10.93	0.00		27.89

$\frac{\Sigma M}{\Sigma V} = \frac{27.89}{10.93} = 2.55$ (0.27 L) ∴ R is WITHIN THE MID THIRD. OK

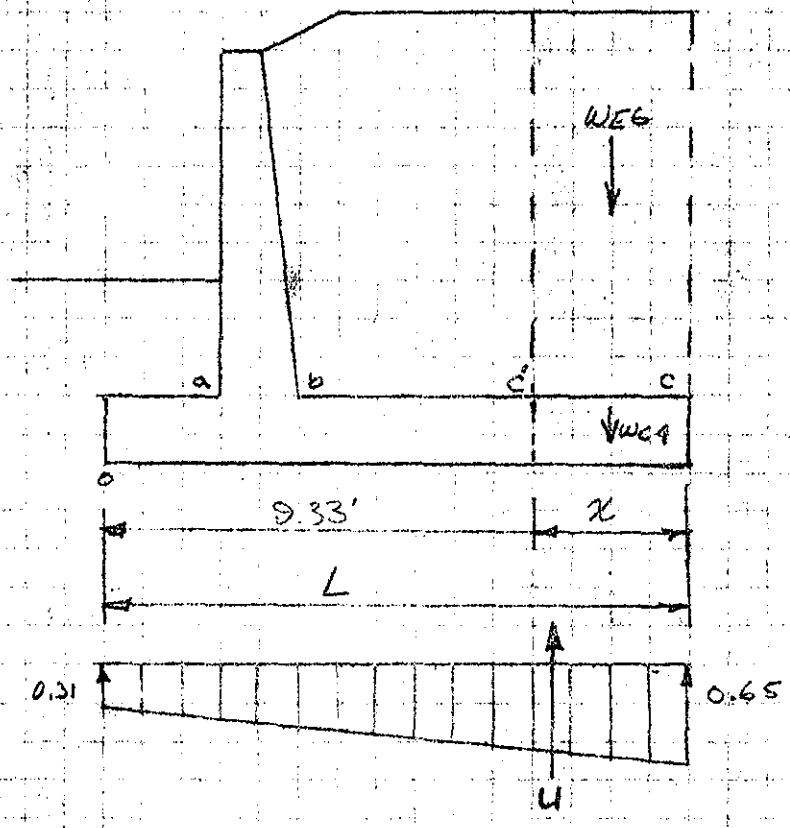
$BP = \frac{2 \times 10.93}{3 \times 2.55} = 2.86$ KSF ← Charts say 2.20 OR 30% OFF. INCREASE OTHER BP's FROM Charts by 30%

$\frac{RM}{OM} = \frac{80.73}{52.84} = 1.53$

F. S. SLIDING = 1.29

THIS EXERCISE SHOWS THAT THE CHARTS FOR REINFORCED CONCRETE RETAINING WALLS by U. S. DOT ARE CLOSE ENOUGH TO DETERMINE TYPICAL CROSS-SECTIONS FOR CANT. RETAINING WALLS.

SUBJECT N. NASHUA
COMPUTATION CANT. WALL 47
COMPUTED BY JF CHECKED BY DATE 9-27-77



$\Sigma V = 15.41 + W_{EG} + W_{CG} - U$

$\Sigma V = 15.41 + 0.125x\,12.17 + 0.15x\,1.5 - \frac{1}{2}(x+9.33)(.96)$

$\Sigma V = 15.41 + 1.52x + 0.23x - 0.48x - 4.48$

$\Sigma V = 1.27x + 10.93$

$\Sigma H' = 5.91^{K}$

$\frac{\Sigma H'}{\Sigma V} \leq 0.45$

$\Sigma H' \leq 0.45 \Sigma V$

$5.91 \leq 0.45\,(1.27x + 10.93)$

$x \geq \left(\frac{5.91}{0.45} - 10.93\right) \div 1.27 = 1.73$ ft.

Base = 11' (add 1.67')

SUBJECT N. NASHUA
COMPUTATION CANT. WALL 418
COMPUTED BY JTE CHECKED BY DATE 9-27-77

$\Sigma M_o = 51.25 + M_{c4} + M_{c4} - M_u$

$\Sigma M_o = 51.25 + (1.52x + 0.23x)\left[\frac{x}{2} + 9.33\right] - \frac{(x+9.33)^3}{6}(2.\times 0.65 + 0.31)$ (0.27)

$\Sigma M_o = 51.25 + 0.88x^2 + 16.33x - 0.27x^2 - 5.01x - 23.36$

$\Sigma M_o = 0.61x^2 + 16.33x + 27.89$

if $x = 1.67'$

$\Sigma M = 56.86$

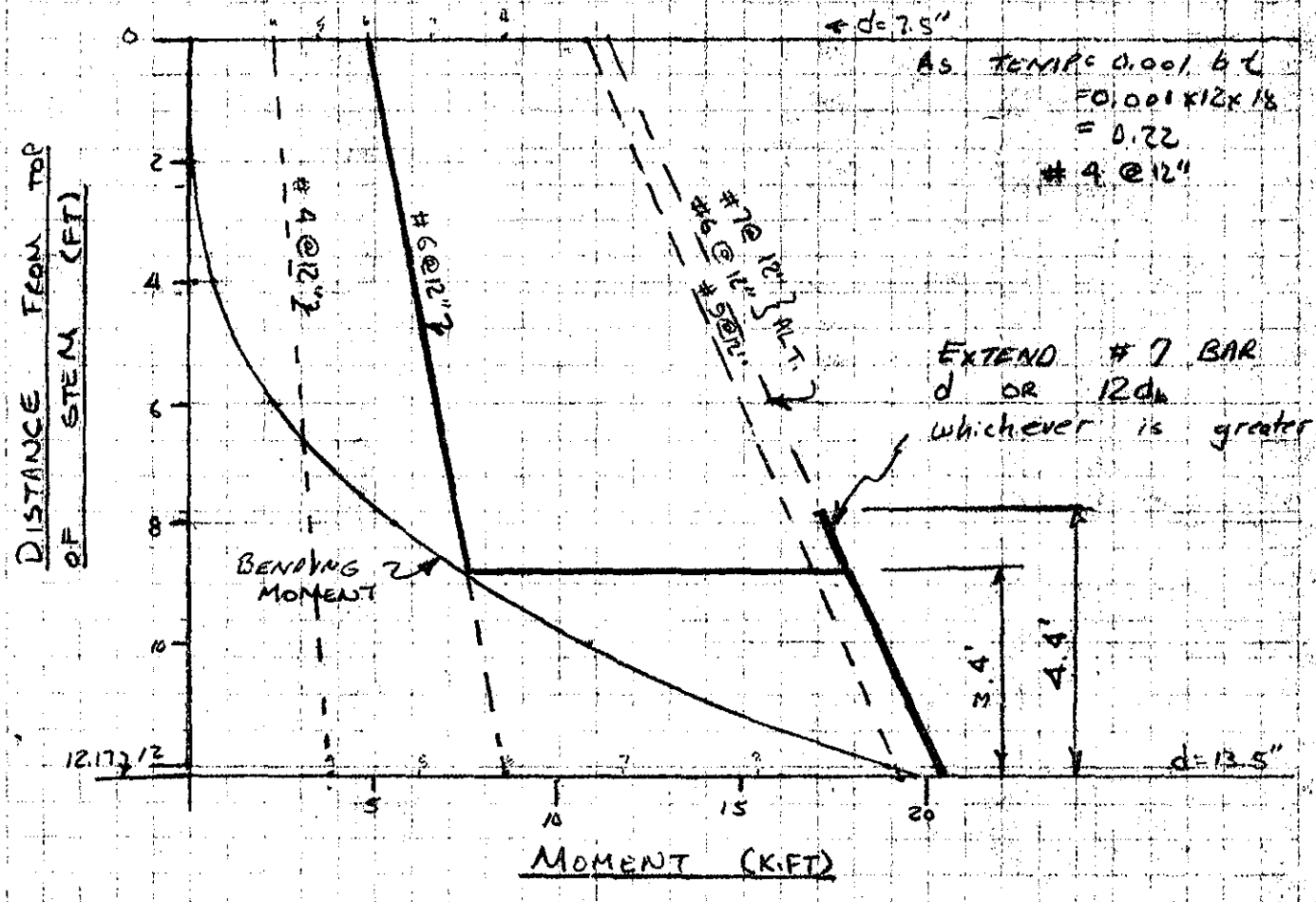
$\Sigma V = 13.05$

$\frac{\Sigma M}{\Sigma V} = 4.36'$ (0.40 L)
$e = 1.19$

$BP = \frac{13.05}{11}\left(1 \pm \frac{6\times 1.19}{11}\right)$

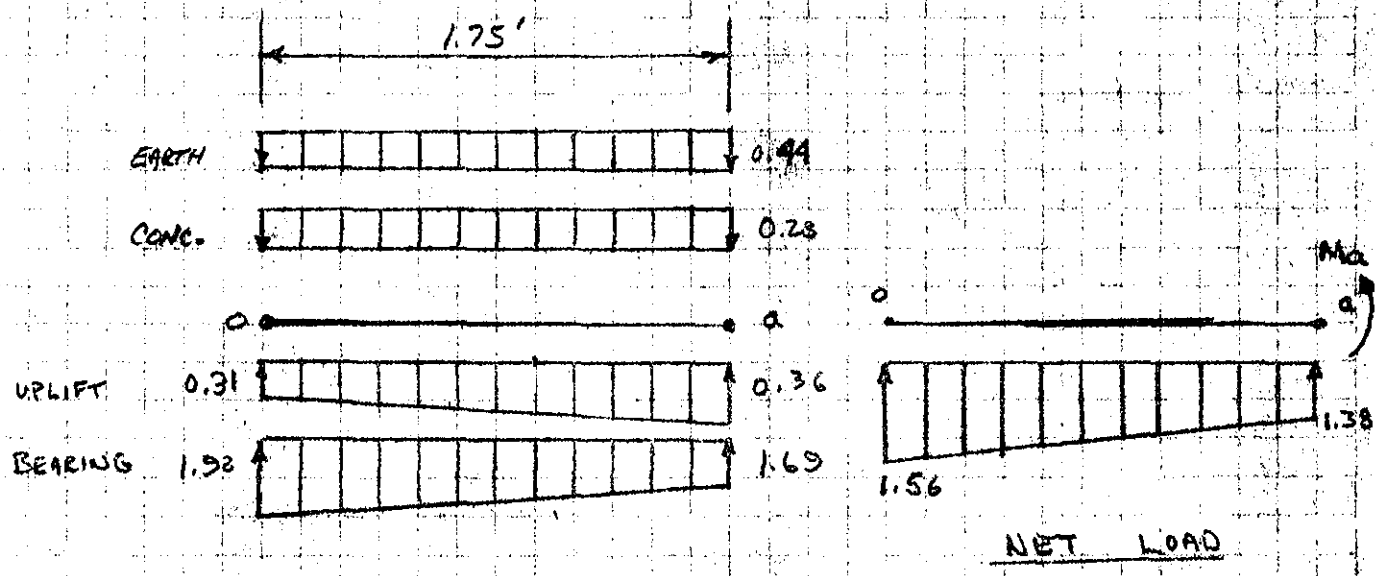
$BP_{MAX} = 1.92$ KSF
$BP_{MIN} = 0.45$ KSF

STEM DESIGN (see pp A(8)) $d_{TOP} = 7.5''$, $d_{BOT} = 13.5''$



SUBJECT N. NASHUA
COMPUTATION CANT. WALL 49
COMPUTED BY JF CHECKED BY DATE 9-27-77

BASE SLAB
TOE DESIGN



$$Ma = \frac{1.75^2}{6}(2 \times 1.56 + 1.38)$$

$Ma = 2.30$ K·FT (TENSION BOT.)

$$d_{REQ} = \left(\frac{2.30}{.152}\right)^{1/2} = 3.89"$$

$d_{prov} = 18 - 6.5 = 11.5"$

$$A_s = \frac{2.30}{1.44 \times 11.5}$$

$A_s = 0.14$ in^2

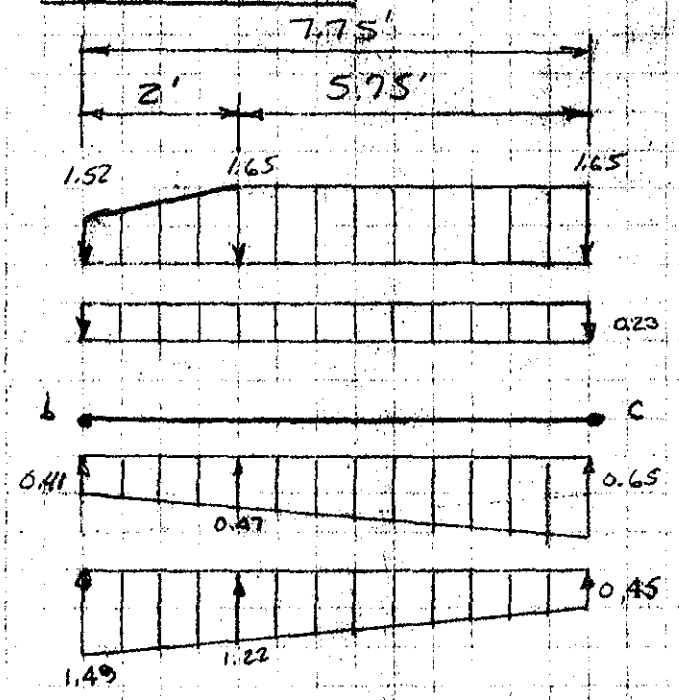
HEEL MOMENT SHOULD BE @ 17.47 K/S @ Face OF STEM

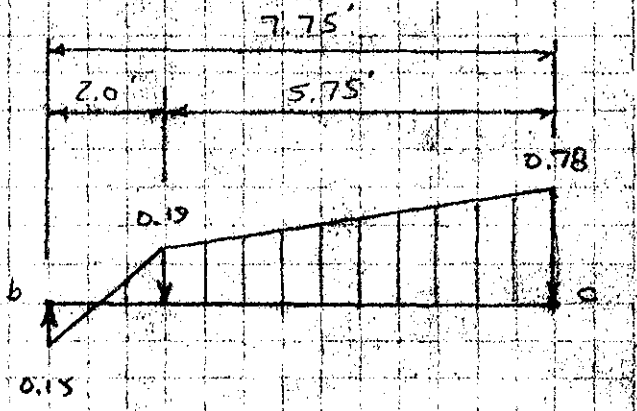
SUBJECT N. NASHUA

COMPUTATION CANT. WALL SO

COMPUTED BY JF CHECKED BY DATE 9-27-77

HEEL DESIGN





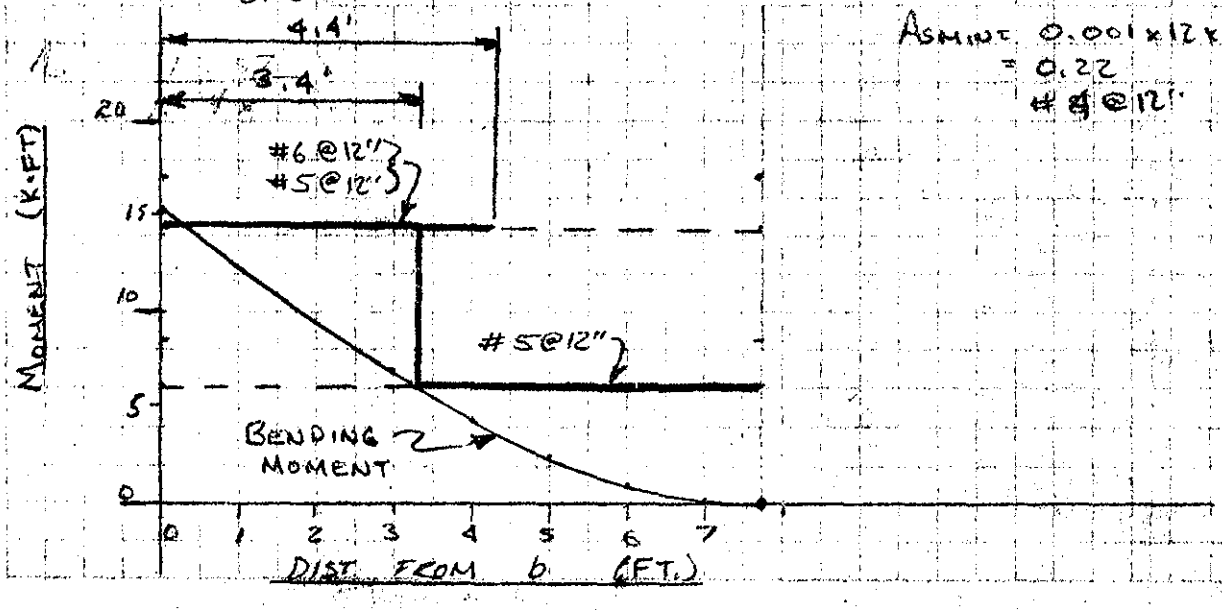
$$M_b = \frac{5.75}{2}(0.19+0.78)\left[2.0 + \frac{5.75(2\times0.78+0.19)}{3(0.19+0.78)}\right] + \frac{2.0^2}{6}(2\times0.19-0.15)$$

$M_b = 15.22 + 0.15$ $\qquad d_{req'd} = 13.5''$

$M_b = 15.37$ K' (TENSION TOP) $\qquad A_s = \frac{15.37}{1.44\times13.5} = 0.79$ in^2

$d_{req} = \sqrt{\frac{15.37}{0.152}} = 10.06''$

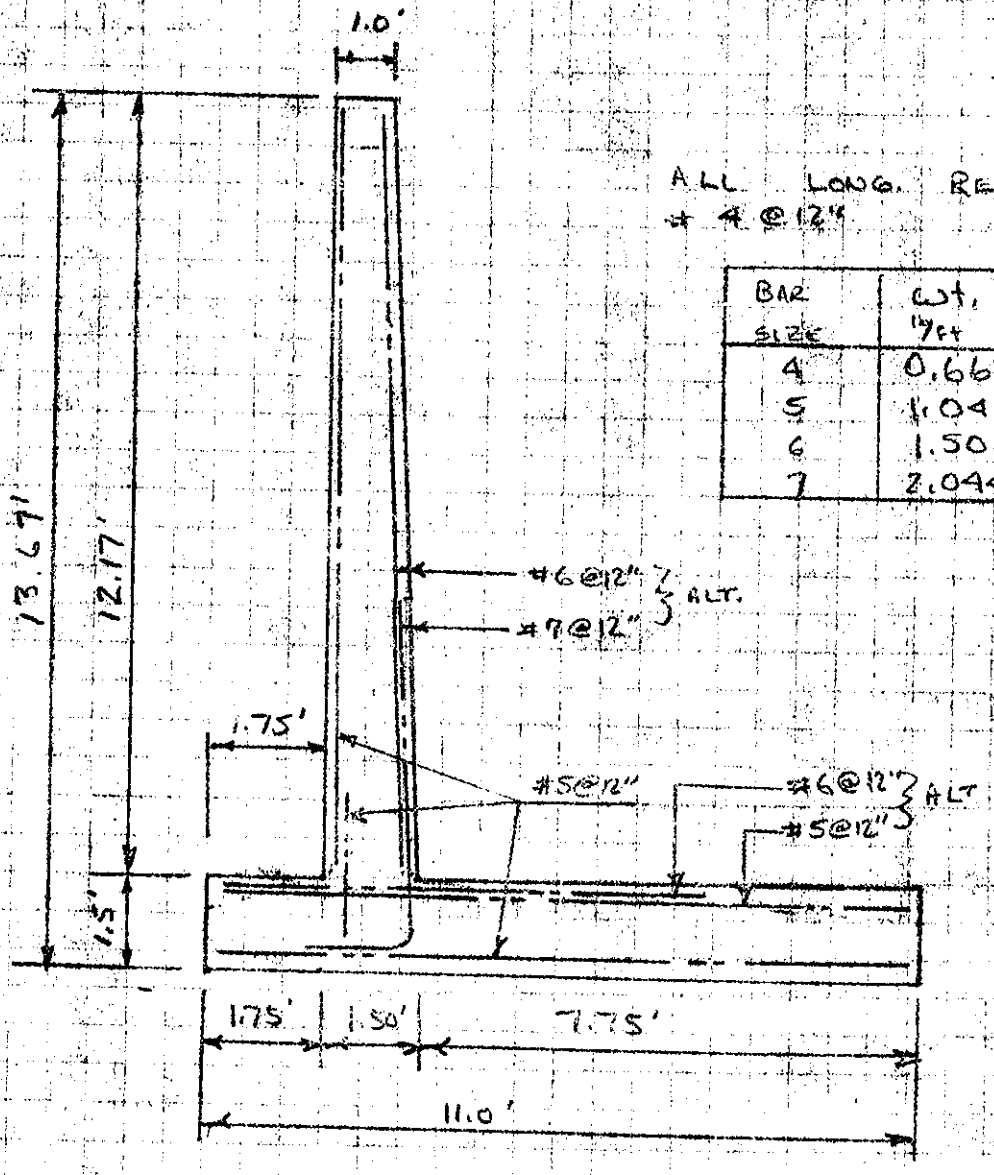
$A_{s\,min} = 0.001\times12\times18$
$= 0.22$
#4 @ 12"



SUBJECT No. NASHUA

COMPUTATION CANT. VS GRAVITY

COMPUTED BY JF CHECKED BY DATE 9-27-77



ALL LONG. REINF. #4 @ 12"

BAR SIZE	wt. #/ft
4	0.668
5	1.043
6	1.502
7	2.044

CONC.

$V = 1.0 \times 12.17 + \frac{1}{2} \times 0.5 \times 12.17 + 1.5 \times 11.0$

$V = 31.71 \text{ ft}^3/\text{ft.}$

$V = 1.17 \text{ yd}^3/\text{FT}$

Charts	H=13.67
V = 1.094	yd^3/FT
W = 75.21	lb/FT

GRAVITY = 2.33 yd^3

REINF.

$L_4 = 11 = 2 \times 23 = 46'$

$L_5 = 12.17 + 2.17 + 2 \times 11 = 36.67'$

$L_6 = 12.17 + 17.65 = 29.82'$

$L_7 = 9.0'$

$W = w_4 L_4 + w_5 L_5 + w_6 L_6 + w_7 L_7$

$W = 0.668 \times 46 + 1.043 \times 36.67 + 1.502 \times 29.82 + 2.044$

$W = 128 \text{ lb/ft.}$

SUBJECT N. NASHUA
COMPUTATION CANT. VS GRAVITY WALL - ECONOMICS 53
COMPUTED BY JF CHECKED BY DATE 6-28-77

FROM ABSTRACT OF SAXONVILLE BIDS CIRCA 1977 THE FOLLOWING AVERAGE PRICES ARE COMPUTED.

CANTILEVER WALL		GRAVITY WALL	
Conc. T-Wall $/YD³	Reinf $/lb.	Conc. Fill $/YD³	
110.00	0.30	80.00	FOR GRAVITY WALL ADD $1.75 / S.F. FOR FORM TO CONC. FILL COST. THERE ARE 28.4 S.F. OF FORMS PER FOOT OF GRAVITY WALL 13.7' HIGH
163.00	0.50	75.00	
190.00	0.45	100.00	
105.00	0.44	100.00	
150.00	0.30	50.00	
Σ - 718.00	1.99	405.00	
AVE. - 143.60	0.40	81.00	

WALL TYPE	ITEM	UNIT COST	QUANTITY		TOTAL $/ FT.	
CANT.	CONC.	$143.60/CY	1.17	C.Y.	168.01	
	REINF	$0.90/lb	128	LB.	51.20	
	TOTAL				219.21	8% LESS
GRAVITY	CONC.	$81.00/CY	2.33	C.Y.	188.73	
	FORM	$1.75/SF	28.4	S.F.	49.70	
	TOTAL				238.43	9% MORE

Since the gravity wall cost is within 10% of the cantilever wall cost, other than pure economy should be considered. The gravity wall is easier to construct and no steel is required. Walls are required at six sites which would mean mobilizing and demobilizing six times. This consideration would give an advantage to the gravity wall. With these facts it is intuitively obvious that a gravity wall should be used.

SUBJECT N. NASHUA
COMPUTATION SUMMARY 54
COMPUTED BY VR CHECKED BY DATE 6-17-77

SUMMARY OF GRAVITY WALL RESULTS

WALL LOCATION	BACK-SLOPE	RESULT. %L LOCATION LC1	RESULT. %L LOCATION LC2	BEAR. PRESS. (KSF) LC1	BEAR. PRESS. (KSF) LC2
CRIB SITE #1	1:2	.34L	.35L	3.33	3.50
CRIB SITE #2 WALL 'A'	1:2	0.32L	0.34L	3.21	3.75
WALL 'B'	1:2	0.45L	0.38L	1.81	2.42
CRIB SITES #5 & #6	7:12	.26L	.39L	3.87	3.05
HARDY FOUNDRY	1:2	.30L	.36L	4.39	4.44
AREA 'A'	—	.15L	—	4.98	—
AREA 'N'	—	.25L	—	1.29	—

ALLOWABLE RESULT. LOCATIONS

LC1 - 0.25L - 0.75L

LC-2 0.33L - 0.67L

DESIGN CONSTANTS:

$\phi = 30°$
$\mu = 0.45$ (F.S. = 1.5)
$K_a = 0.33$
$K_p = 3.00$

$\gamma_{SAT} = 125$ PCF
$\gamma_{SUB} = 62.5$ PCF
$\gamma_{DRY} = 100.$ PCF

$\gamma_{WAT} = 62.5$ PCF
$\gamma_{conc} = 150$ PCF

LC-1 RAPID DRAW DOWN, DRAINS 50% EFFECTIVE

LC-2 NORMAL CONDITION, DRY EARTH, 2' TRAFFIC SURCHARGE

ATTACHMENT E

STAGE DAMAGE CURVES

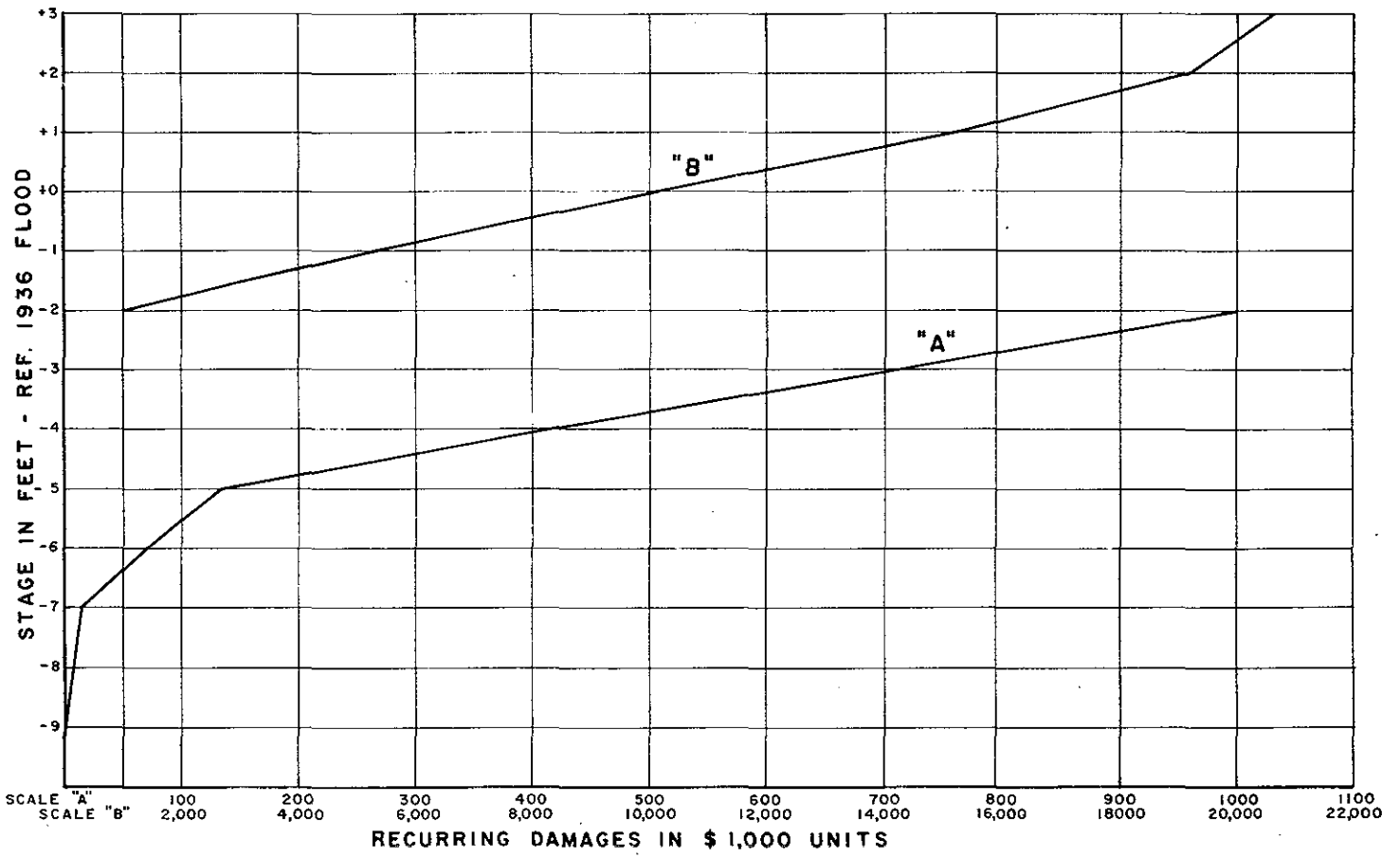
ECONOMIC ZONES

Zone No.	ECONOMIC ZONES (Includes Damages Hydraulic Controls)
3	Syphon Dam to TW Duck Mill Dam-right bank only
4	HW Duck Mill Dam TW Arden Dam
5	HW Arden Dam to TW FG & E Dam - both banks
6	HW FG & E Dam to RR Br. upstream Sawyer Passway- both banks
7	RR Br. upstream of Sawyer Passway to Water St. Br.- both banks west and South of the RR
8	Water St. Br. to Cushing St. Br. - both banks west and south of Railroad Bridge
9	RR Br. above Sawyer Passway to Cushing St. Br. - east and north of of RR and west of Willow St. extended
10	Cushing St. Br. to Putnam St. Br. - both banks
11	Putnam St. to RR Br. below Staffgage- rt. bank only
12	Putnam St. Br. to Rollstone St. Br.- left bank only
13	HW RR Bridge below Staffgage

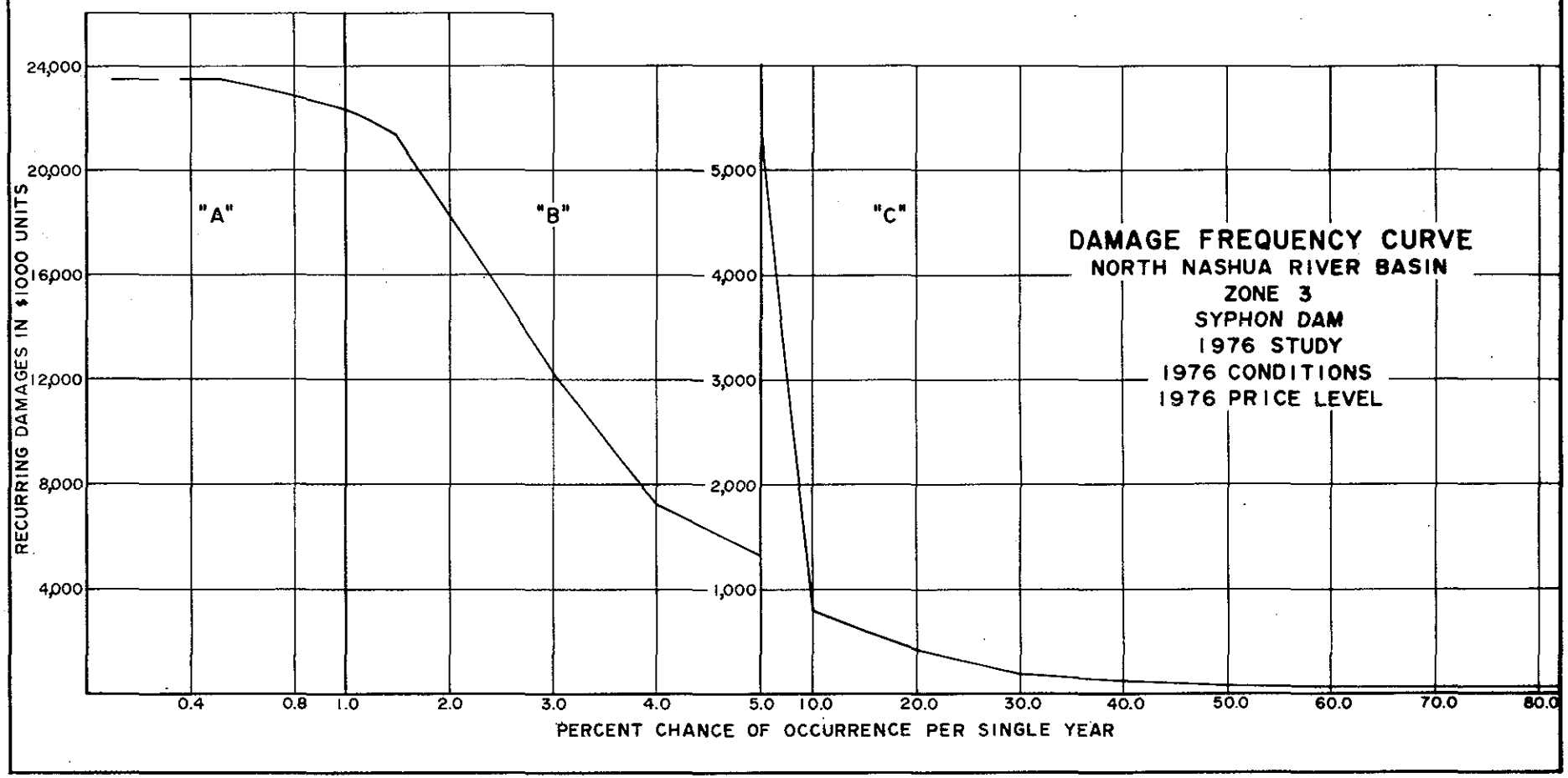
Zone No.	ECONOMIC ZONES (Zone Lights)
14	Rollstone St. bridge to lower River St. Bridge - left bank
15	Lower River St. bridge to Sheldon St. bridge - left bank
16	Sheldon St. bridge to Sta. 235+00 - left bank
17	Rollstone St. bridge to Upper River St. bridge - right bank
18	Sta. 235+00 to Oak Hill Rd bridge - Left bank
19	Upper River St. bridge to Oak Hill Road - right bank
20	Oak Hill Road bridge to former Cowee's damsite

STAGE DAMAGE CURVE

NORTH NASHUA RIVER BASIN
ZONE 3
SYPHON DAM
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL

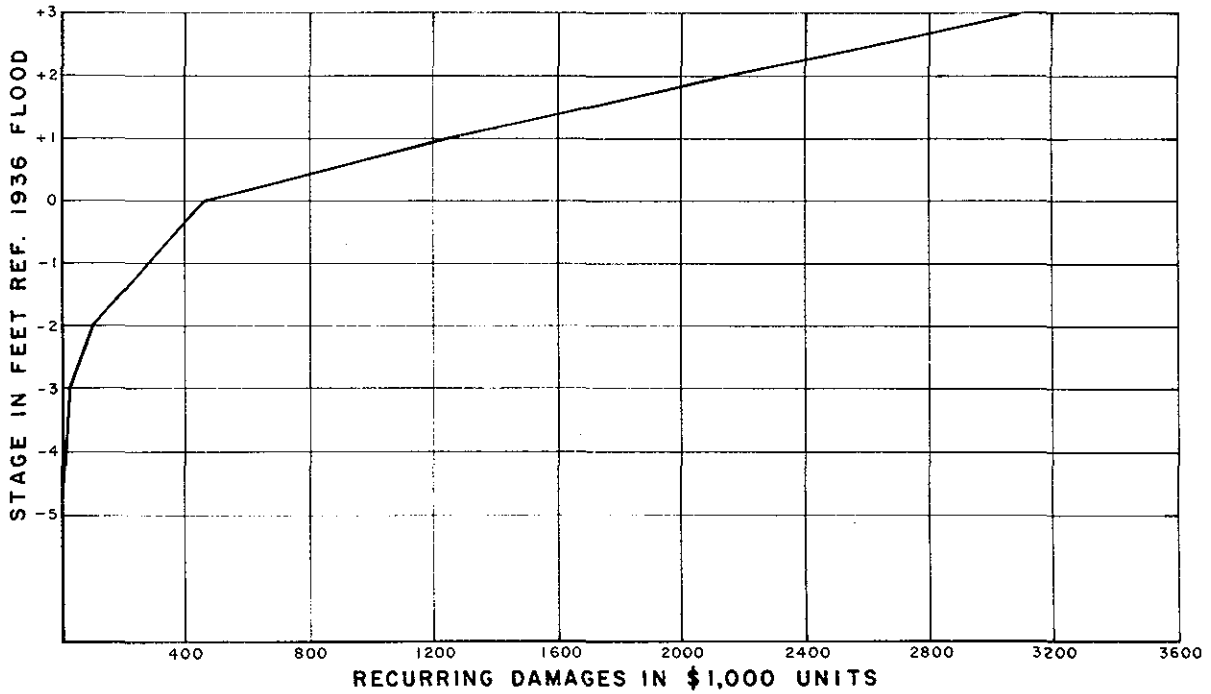


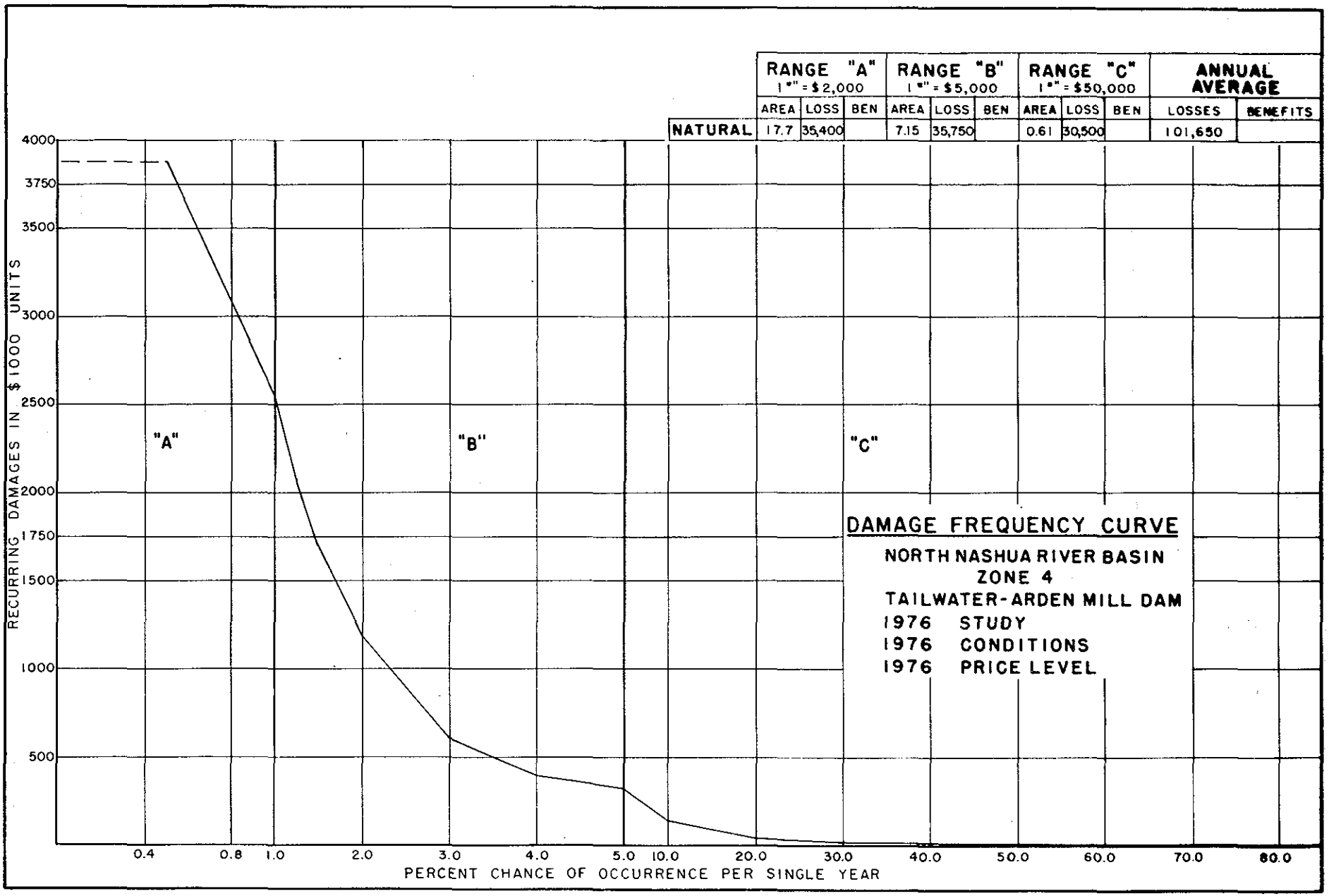
	RANGE "A" 1" = $16,000			RANGE "B" 1" = $40,000			RANGE "C" 1" = $100,000			ANNUAL AVERAGE	
	AREA	LOSS	BEN	AREA	LOSS	BEN	AREA	LOSS	BEN	LOSSES	BENEFIT
NATURAL	14.31	228,960	—	13.16	526,400	—	2.92	292,000	—	1,047,360	—

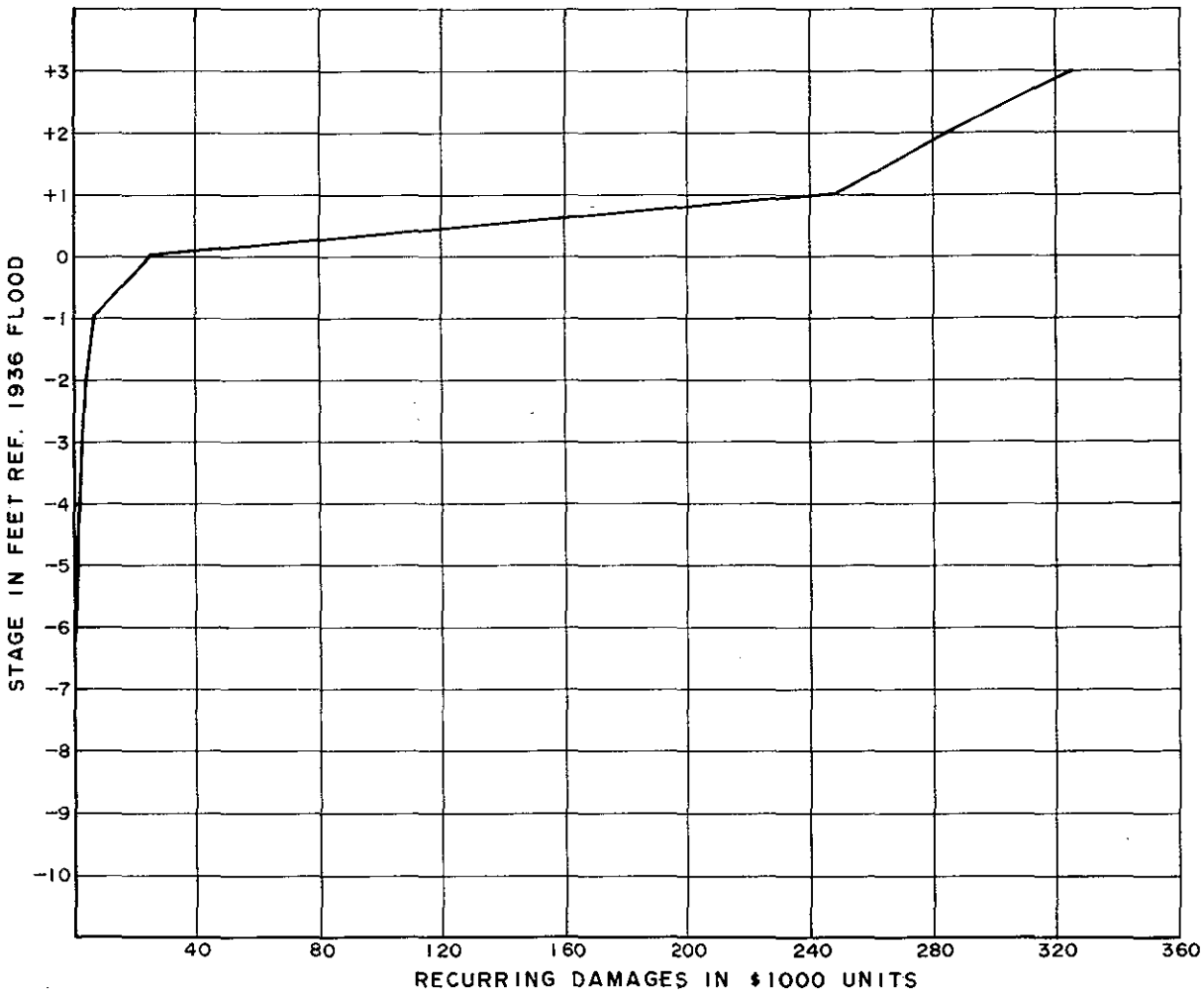


STAGE DAMAGE CURVE

NORTH NASHUA RIVER BASIN
ZONE 4
TAILWATER - ARDEN MILL DAM
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL



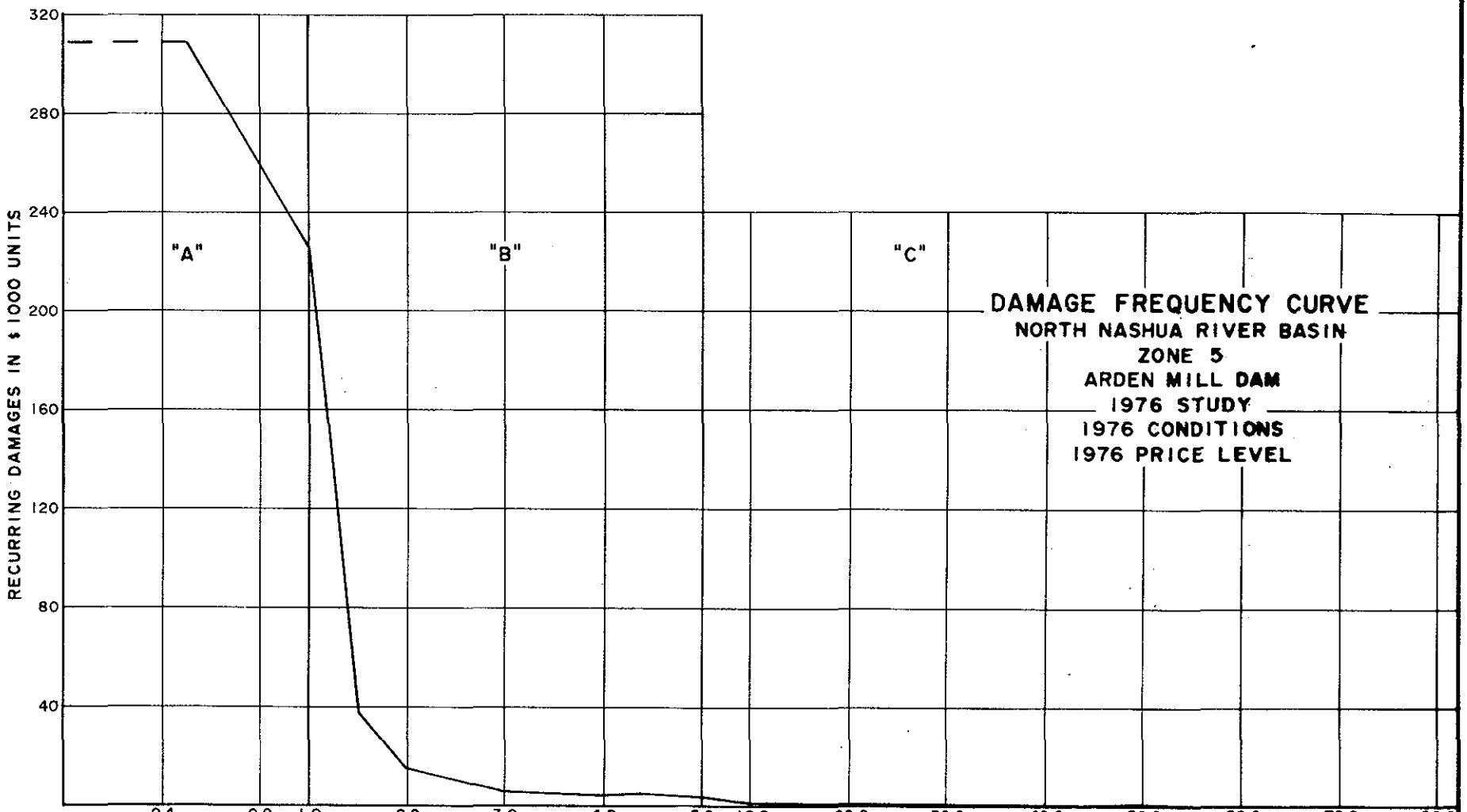

RANGE "A" 1" = $2,000
RANGE "B" 1" = $5,000
RANGE "C" 1" = $50,000
ANNUAL AVERAGE
AREA LOSS BEN AREA LOSS BEN AREA LOSS BEN LOSSES BENEFITS
NATURAL 17.7 35,400 7.15 35,750 0.61 30,500 101,650
RECURRING DAMAGES IN $1000 UNITS
4000
3750
3500
3000
2500
2000
1750
1500
1000
500
"A"
"B"
"C"
0.4 0.8 1.0 2.0 3.0 4.0 5.0 10.0 20.0 30.0 40.0 50.0 60.0 70.0 80.0
PERCENT CHANCE OF OCCURRENCE PER SINGLE YEAR
DAMAGE FREQUENCY CURVE
NORTH NASHUA RIVER BASIN
ZONE 4
TAILWATER-ARDEN MILL DAM
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL



STAGE DAMAGE CURVE

NORTH NASHUA RIVER BASIN
ZONE 5
ARDEN MILL DAM
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL

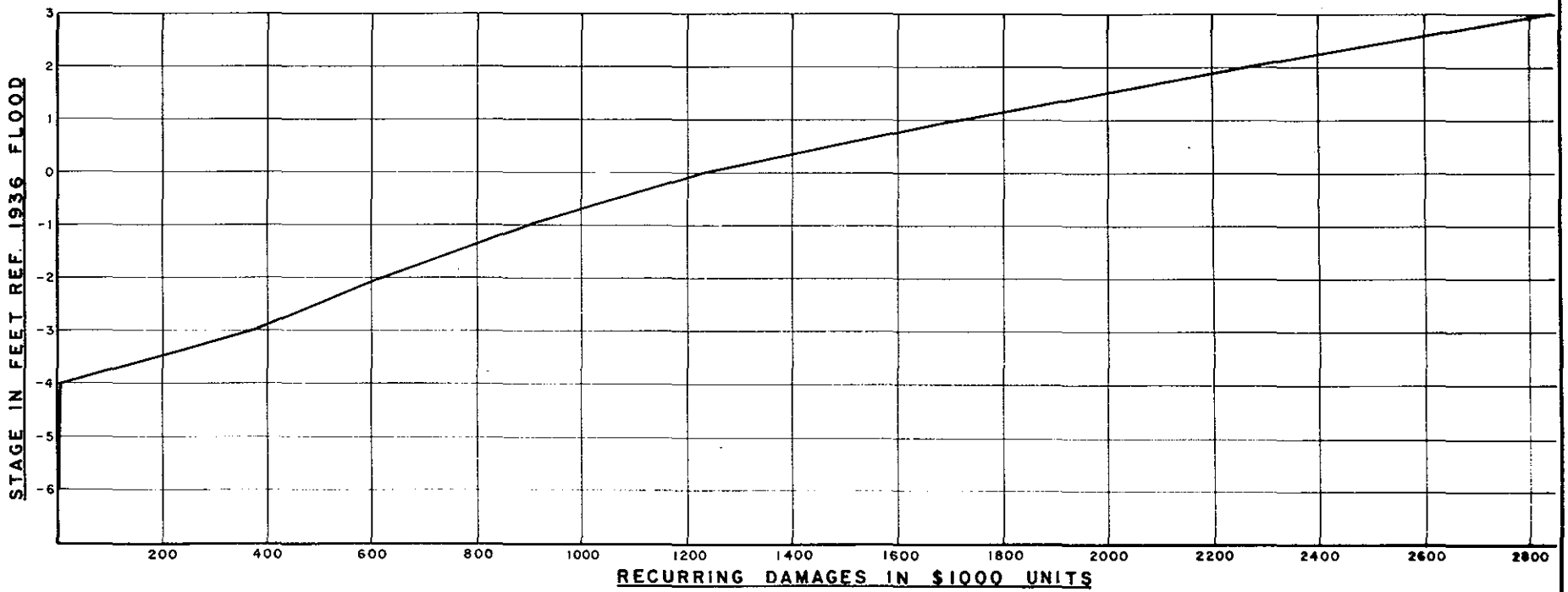
	RANGE "A" 1" = $160			RANGE "B" 1" = $400			RANGE "C" 1" = $4,000			ANNUAL AVERAGE	
	AREA	LOSS	BEN	AREA	LOSS	BEN	AREA	LOSS	BEN	LOSSES	BENEFITS
NATURAL	18.01	2882.0		2.445	978		0.211	846		4706	



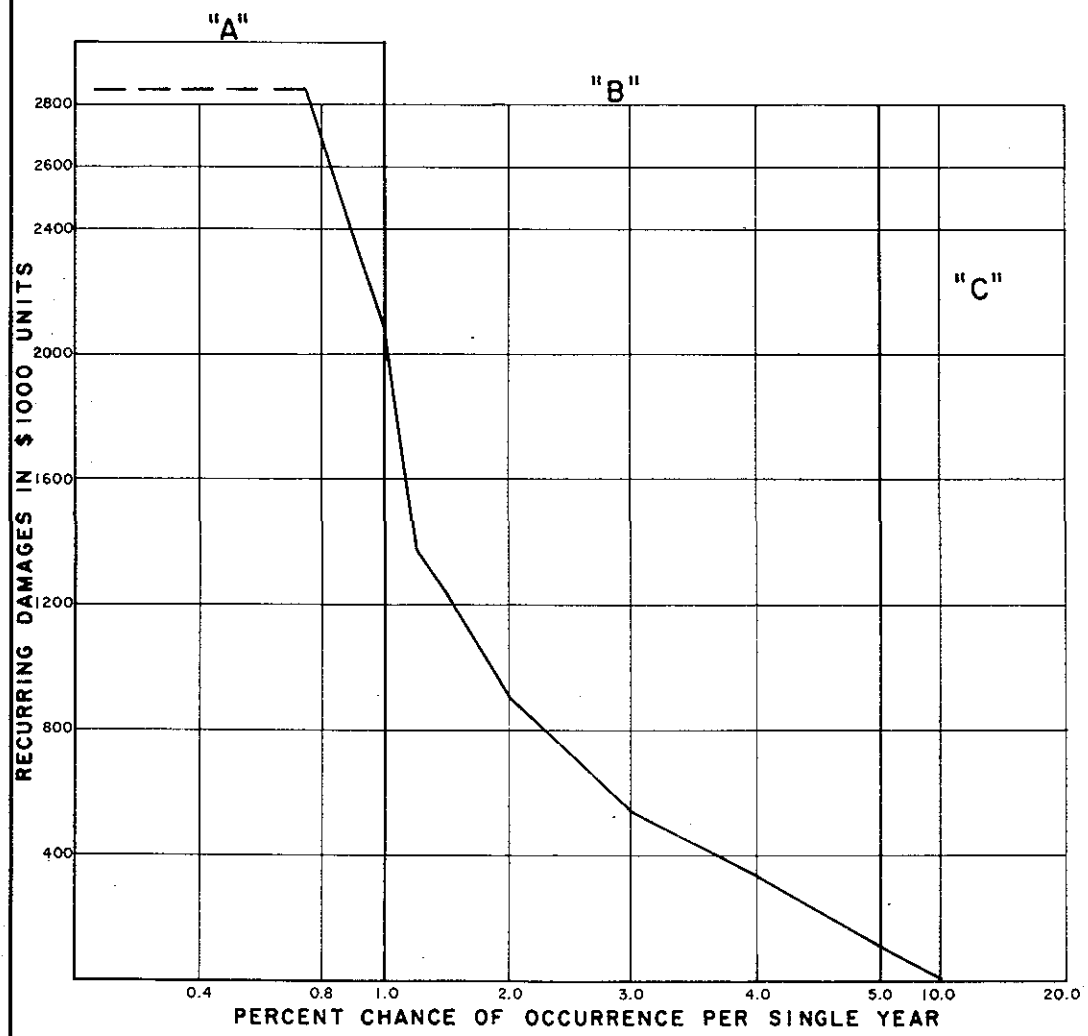
DAMAGE FREQUENCY CURVE
NORTH NASHUA RIVER BASIN
ZONE 5
ARDEN MILL DAM
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL

STAGE DAMAGE CURVE

NORTH NASHUA RIVER BASIN
ZONE 6
SAWYERS PASSWAY
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL

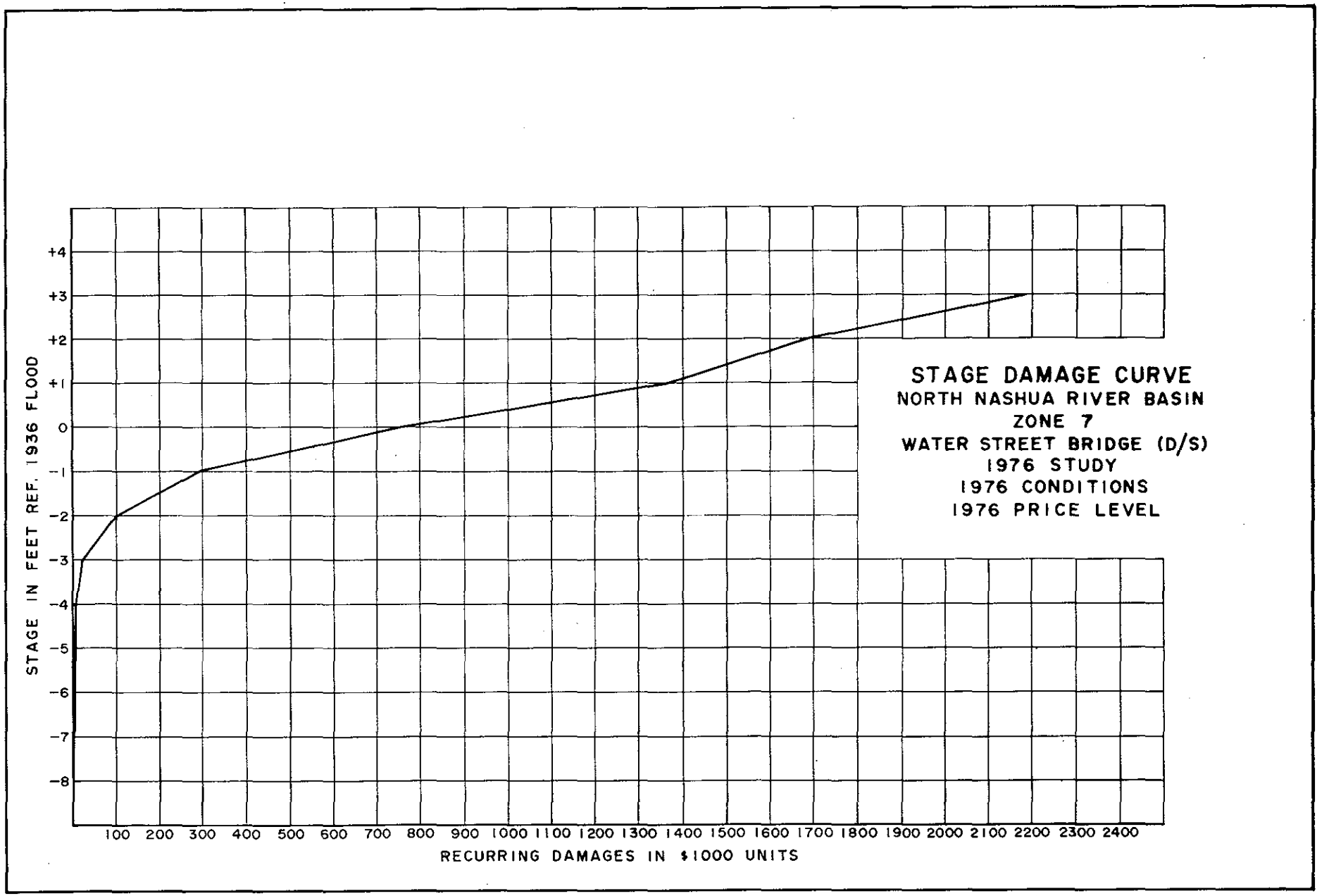


	RANGE "A" 1" = $1,600			RANGE "B" 1" = $4,000			RANGE "C" 1" = $40,000			ANNUAL AVERAGE	
	AREA	LOSS	BEN	AREA	LOSS	BEN	AREA	LOSS	BEN	LOSSES	BENEFITS
NATURAL	17.20	27,520	—	6.77	27,080	—	.075	3,000	—	57,600	—

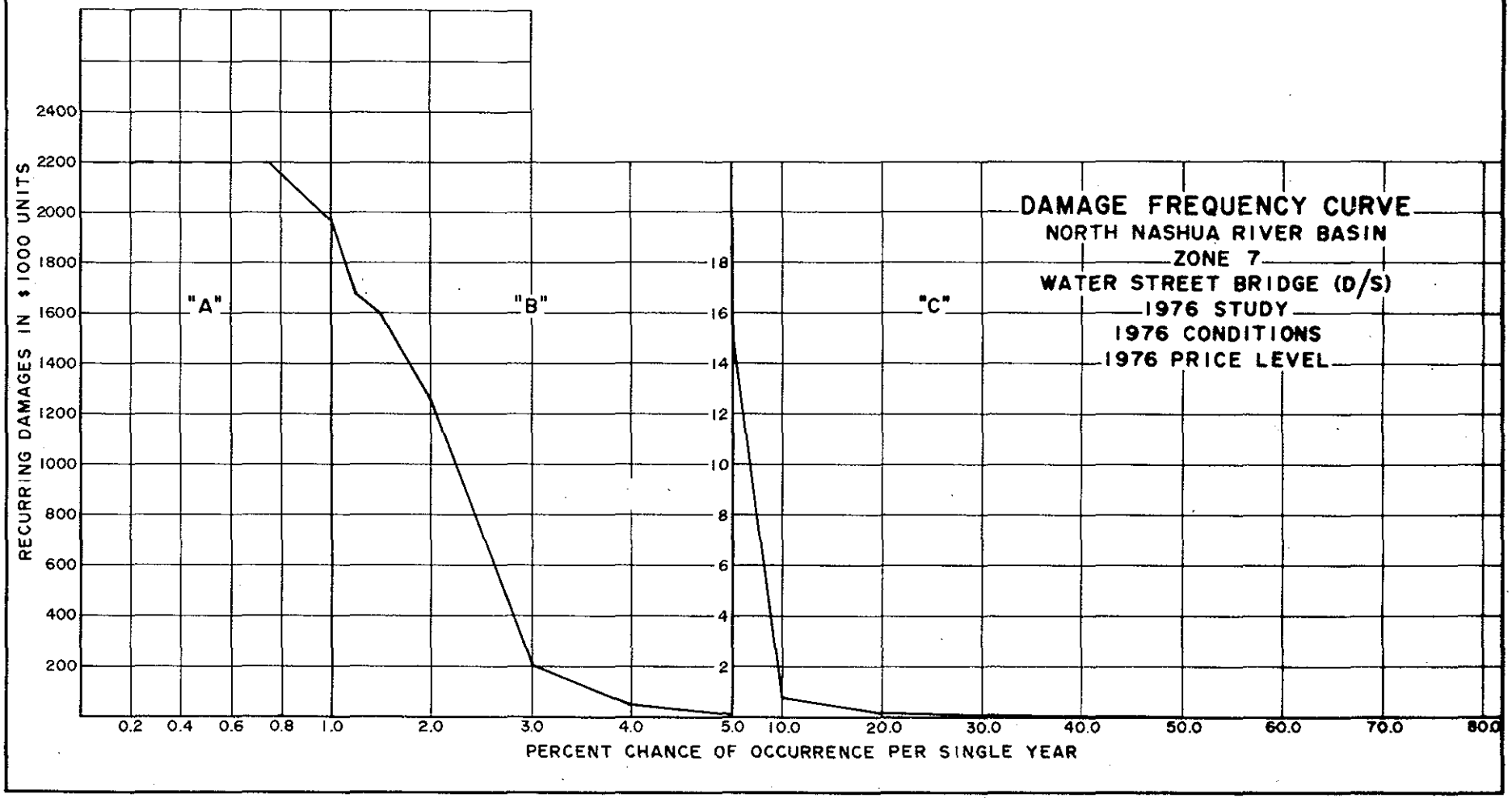


DAMAGE FREQUENCY CURVE

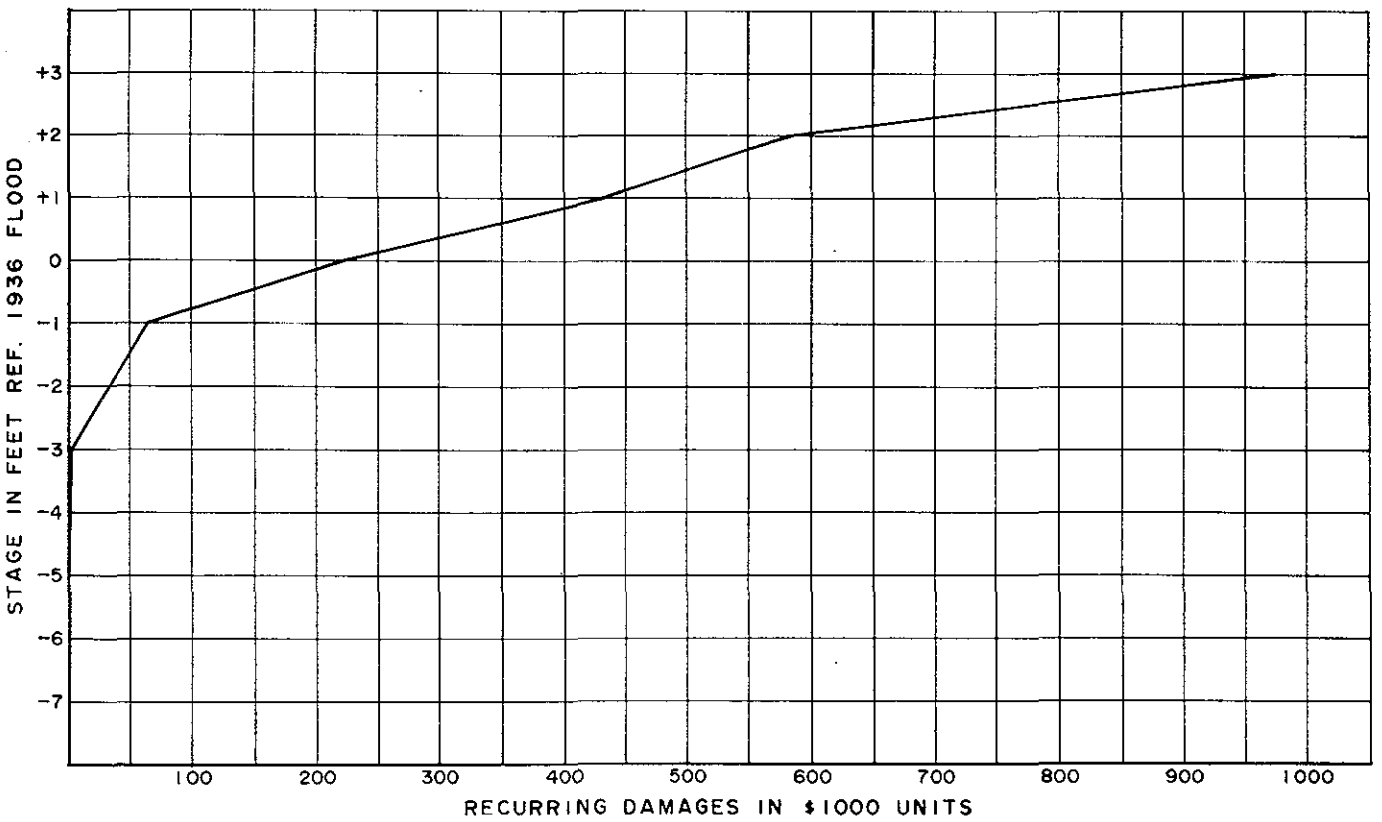
NORTH NASHUA RIVER BASIN
ZONE 6
SAWYER PASSWAY
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL


STAGE DAMAGE CURVE
NORTH NASHUA RIVER BASIN
ZONE 7
WATER STREET BRIDGE (D/S)
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL
STAGE IN FEET REF. 1936 FLOOD
+4
+3
+2
+1
0
-1
-2
-3
-4
-5
-6
-7
-8
100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 2400
RECURRING DAMAGES IN $1000 UNITS

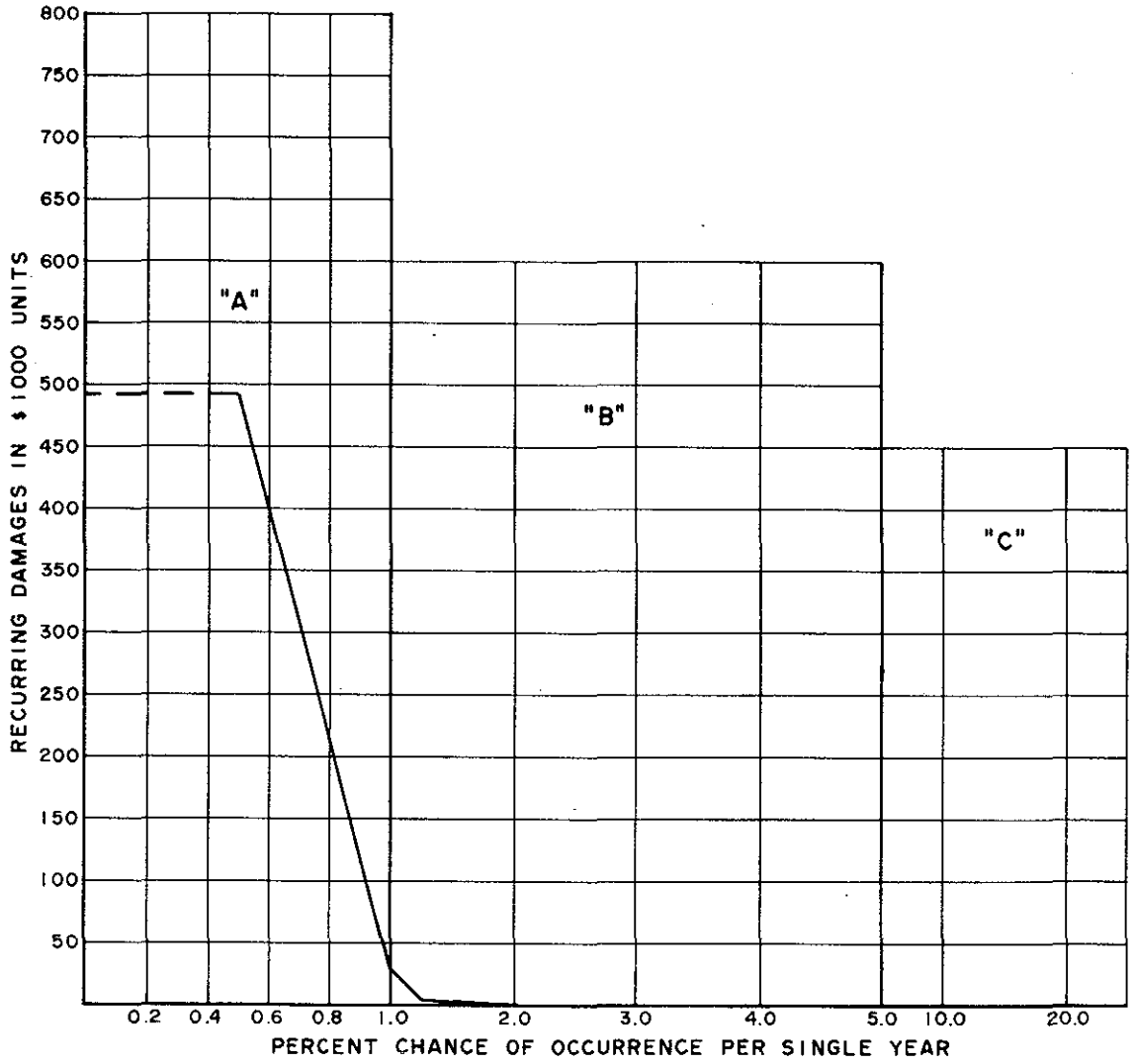
	RANGE "A" 1" = $1600			RANGE "B" 1" = $4,000			RANGE "C" 1" = $400			ANNUAL AVERAGE	
	AREA	LOSS	BEN	AREA	LOSS	BEN	AREA	LOSS	BEN	LOSSES	BENEFITS
NATURAL	13.50	21,600	—	6.30	25,200	—	1.30	520	—	47,320	—



STAGE DAMAGE CURVE
NORTH NASHUA RIVER BASIN
ZONE 8
WATER STREET BRIDGE (U/S)
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL



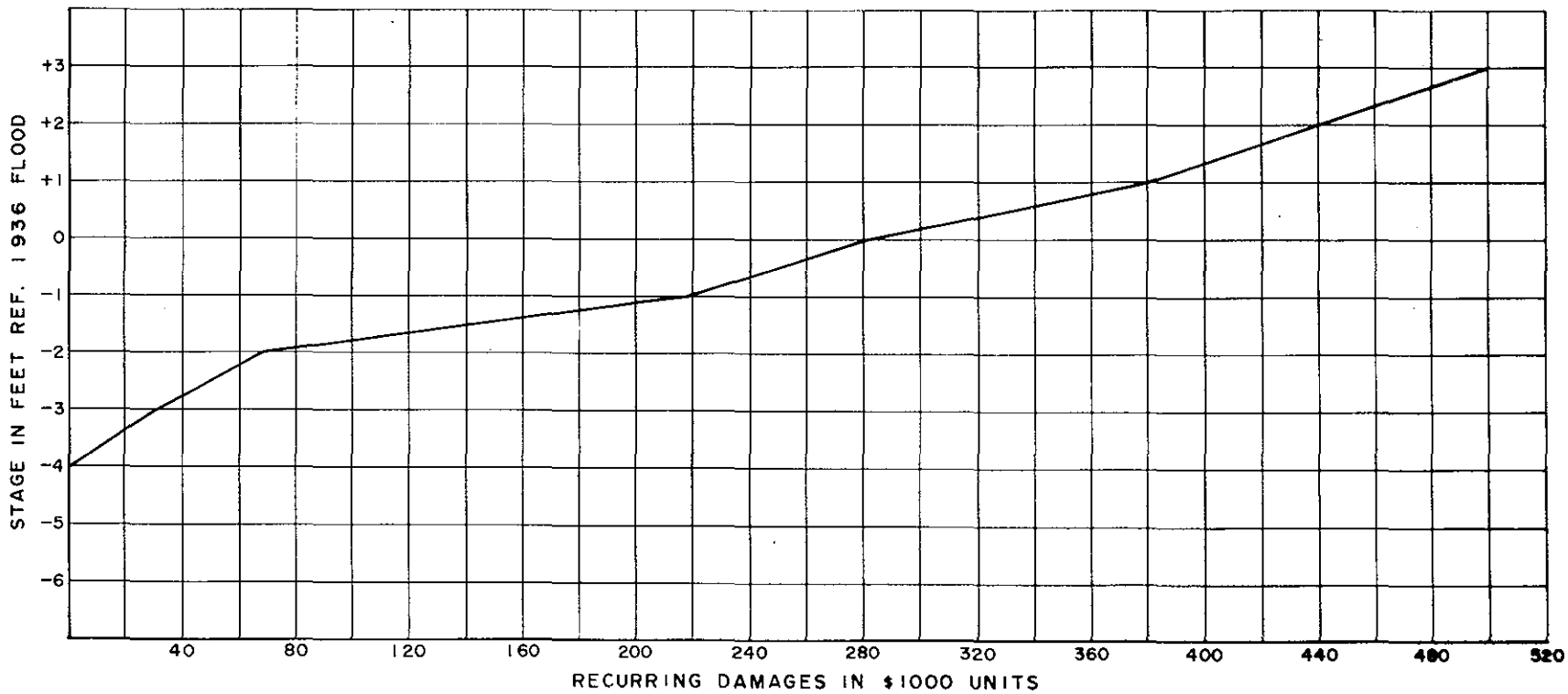
	RANGE "A" 1" = $ 400			RANGE "B" 1" = $ 1,000			RANGE "C" 1" = $ 10,000			ANNUAL AVERAGE	
	AREA	LOSS	BEN	AREA	LOSS	BEN	AREA	LOSS	BEN	LOSSES	BENEFITS
NATURAL	9.36	3744	—	.050	50	—	0	—	—	3794	—



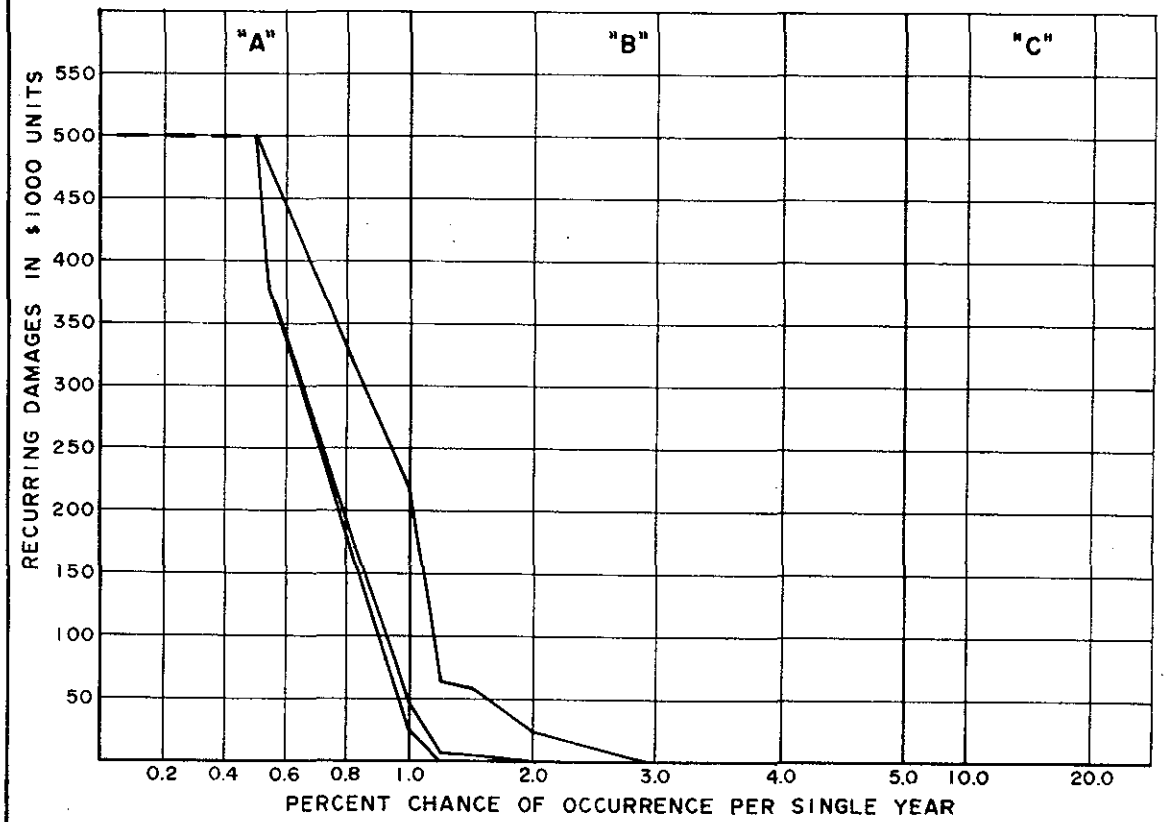
DAMAGE FREQUENCY CURVE

NORTH NASHUA RIVER BASIN
ZONE 8
WATER STREET BRIDGE (U/S)
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL

STAGE DAMAGE CURVE
NORTH NASHUA RIVER BASIN
ZONE 9
CUSHING STREET BRIDGE (U/S)
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL



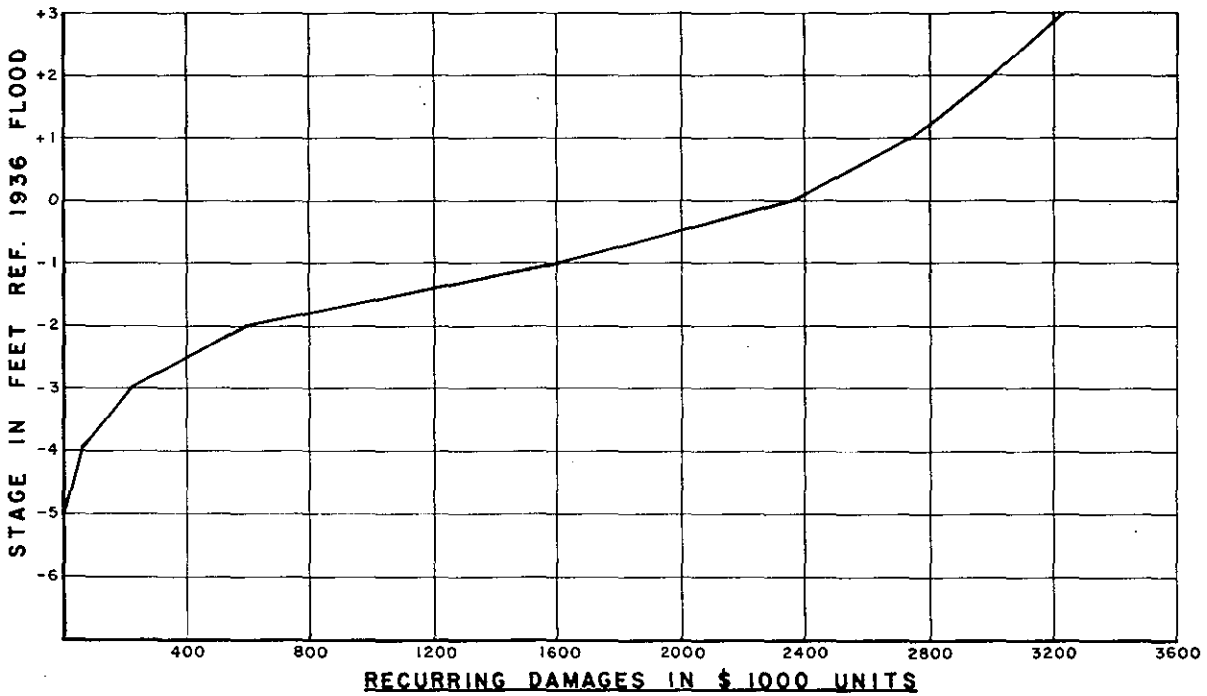
	RANGE "A" 1"= $400			RANGE "B" 1"= $1,000			RANGE "C" 1"= $10,000			ANNUAL AVERAGE	
	AREA	LOSS	BEN	AREA	LOSS	BEN	AREA	LOSS	BEN	LOSSES	BENEFITS
NATURAL	9.18	3672	648	.100	100	750	0	0	–	3772	1398
POSSIBLE (F)	10.80	4320	–	.850	850	–	0	0	–	5170	–
W/REHAB	9.08	3632	688	.033	33	817	0	0	–	3665	1505
1990 BEN											
1976 BEN			40			67					107



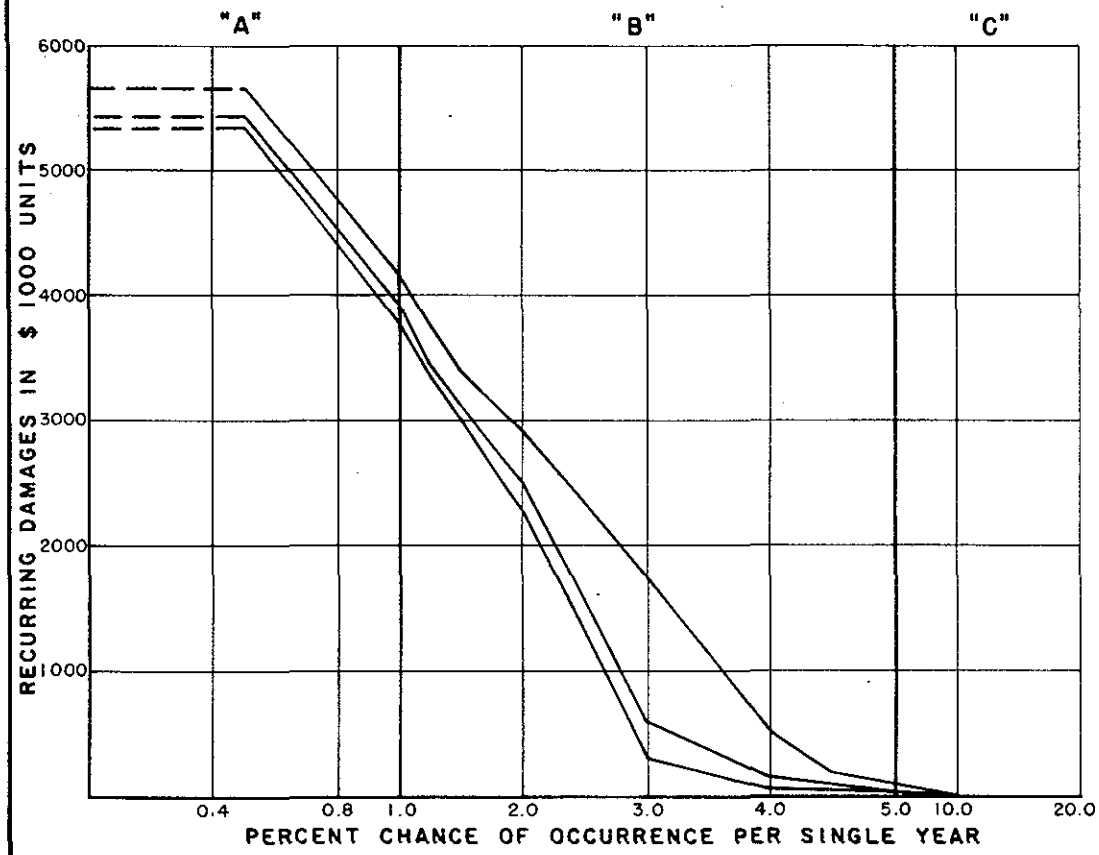
DAMAGE FREQUENCY CURVE
NORTH NASHUA RIVER BASIN
ZONE 9
CUSHING STREET BRIDGE (U/S)
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL

STAGE DAMAGE CURVE

NORTH NASHUA RIVER BASIN
ZONE 10
R. R. BRIDGE U/S
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL



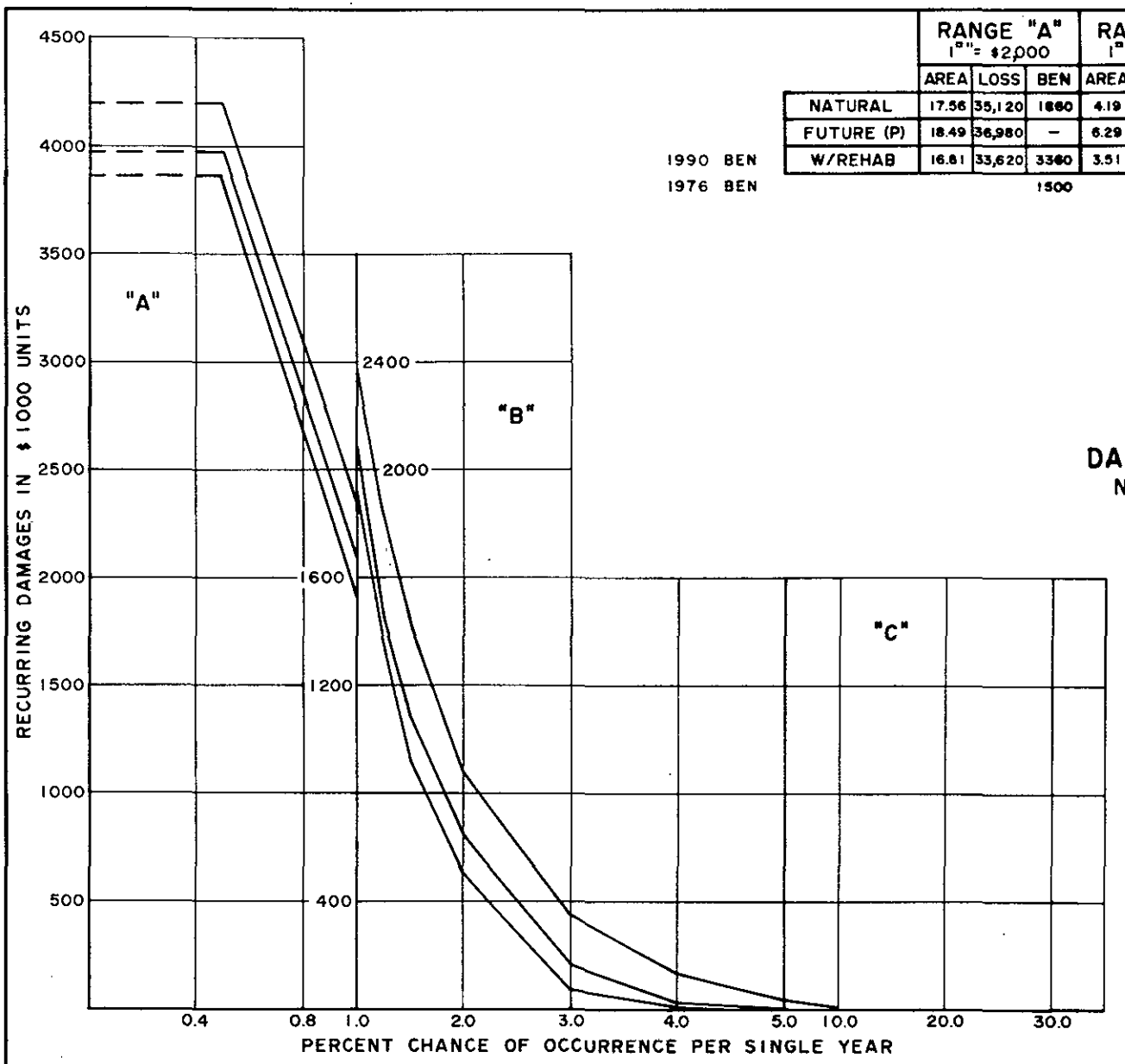
		RANGE "A" 1" = $4,000			RANGE "B" 1" = $10,000			RANGE "C" 1" = $100,000			ANNUAL AVERAGE	
		AREA	LOSS	BEN	AREA	LOSS	BEN	AREA	LOSS	BEN	LOSSES	BENEFITS
	NATURAL	12.7	50,800	2,000	5.2	52,000	21,000	0.0125	1,250	1,750	104,050	24,750
	POSSIBLE(F)	13.2	52,800		7.3	73,000		0.03	3,000		128,800	
1990 BEN	W/REHAB	12.4	49,600	3,200	4.5	45,000	28,000	0	—	3,000	94,600	34,200
1976 BEN				1,200			7,000			1,250		9,450



DAMAGE FREQUENCY CURVE

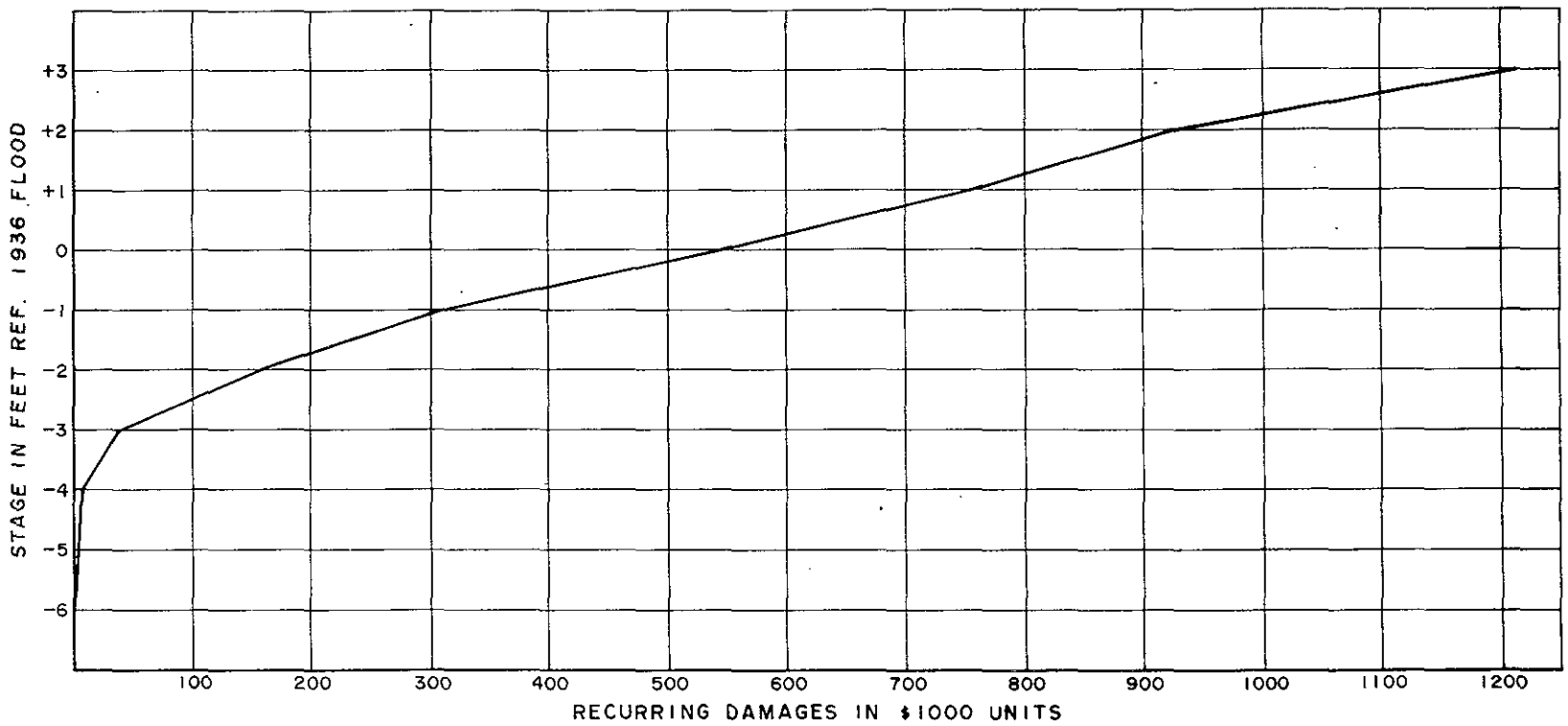
NORTH NASHUA RIVER BASIN
ZONE 10
R R BRIDGE (U/S)
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL

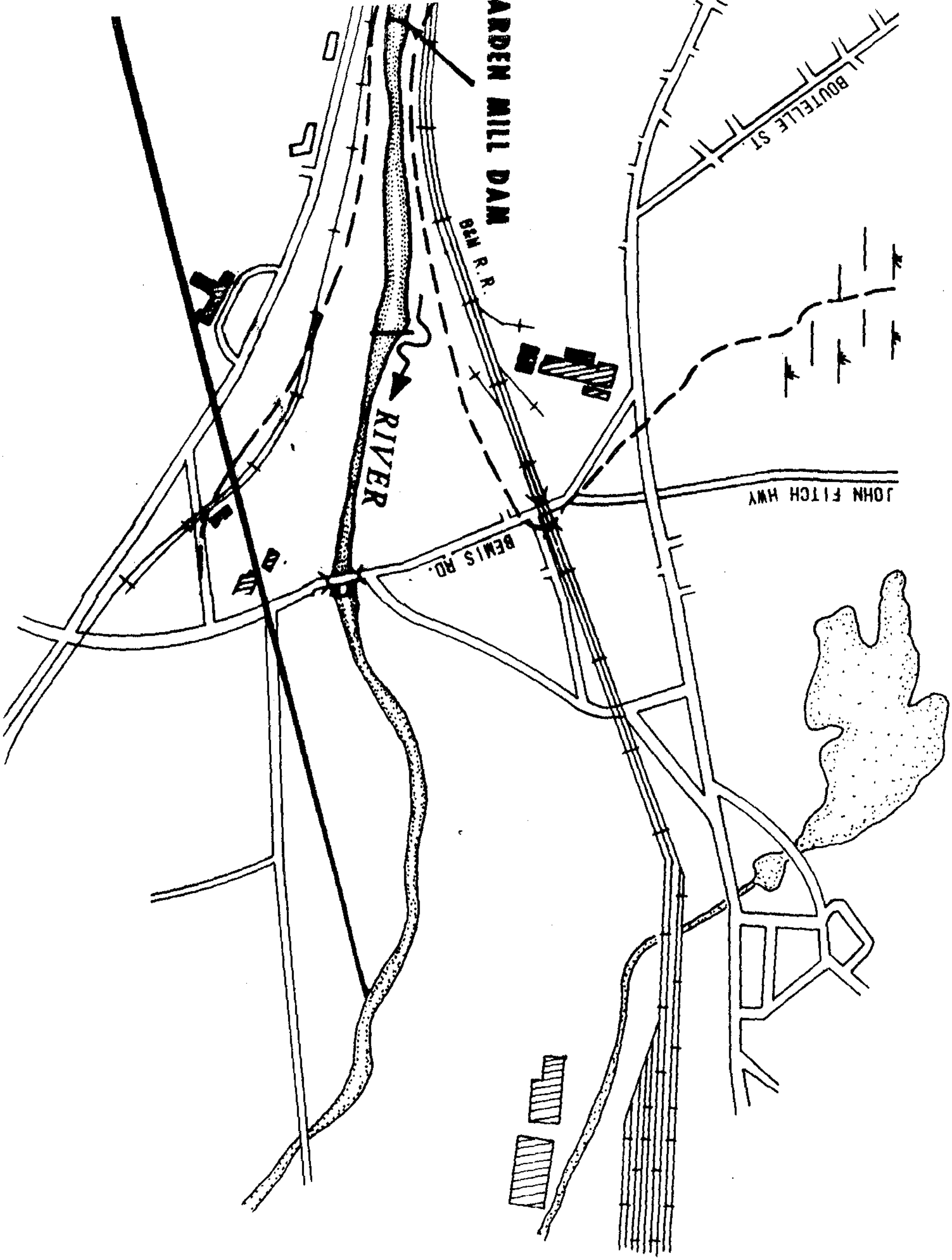
	RANGE "A" 1"= $2,000			RANGE "B" 1"= $4,000			RANGE "C" 1"= $40,000			ANNUAL AVERAGE	
	AREA	LOSS	BEN	AREA	LOSS	BEN	AREA	LOSS	BEN	LOSSES	BENEFITS
NATURAL	17.56	35,120	1660	4.19	16,760	8400	—	—	1200	51,880	11,600
FUTURE (P)	18.49	36,980	—	6.29	25,160	—	.030	1200	—	62,140	—
W/REHAB	16.81	33,620	3360	3.51	14,040	11,120	—	—	1200	47,660	15,480
1990 BEN			1500			2720			0		4220
1976 BEN											



DAMAGE FREQUENCY CURVE
NORTH NASHUA RIVER BASIN
ZONE II
R.R. BRIDGE #7 (U/S)
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL

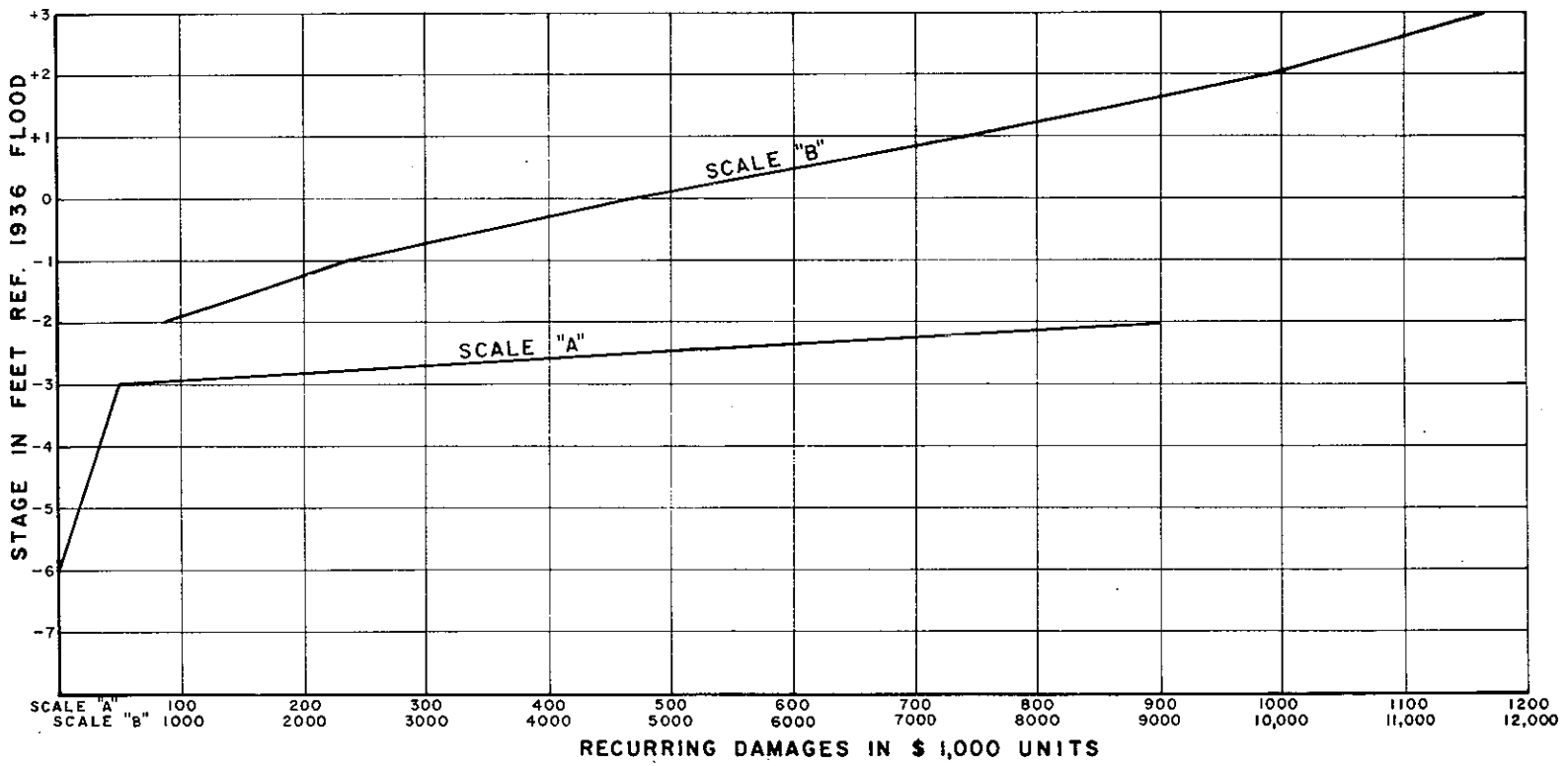
STAGE DAMAGE CURVE
NORTH NASHUA RIVER BASIN
ZONE II
R.R. BRIDGE #7 (U/S)
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL




ARDEN MILL DAM
B&M R.R.
RIVER
BEMIS RD.
JOHN FITCH HWY
BOUTELLE ST

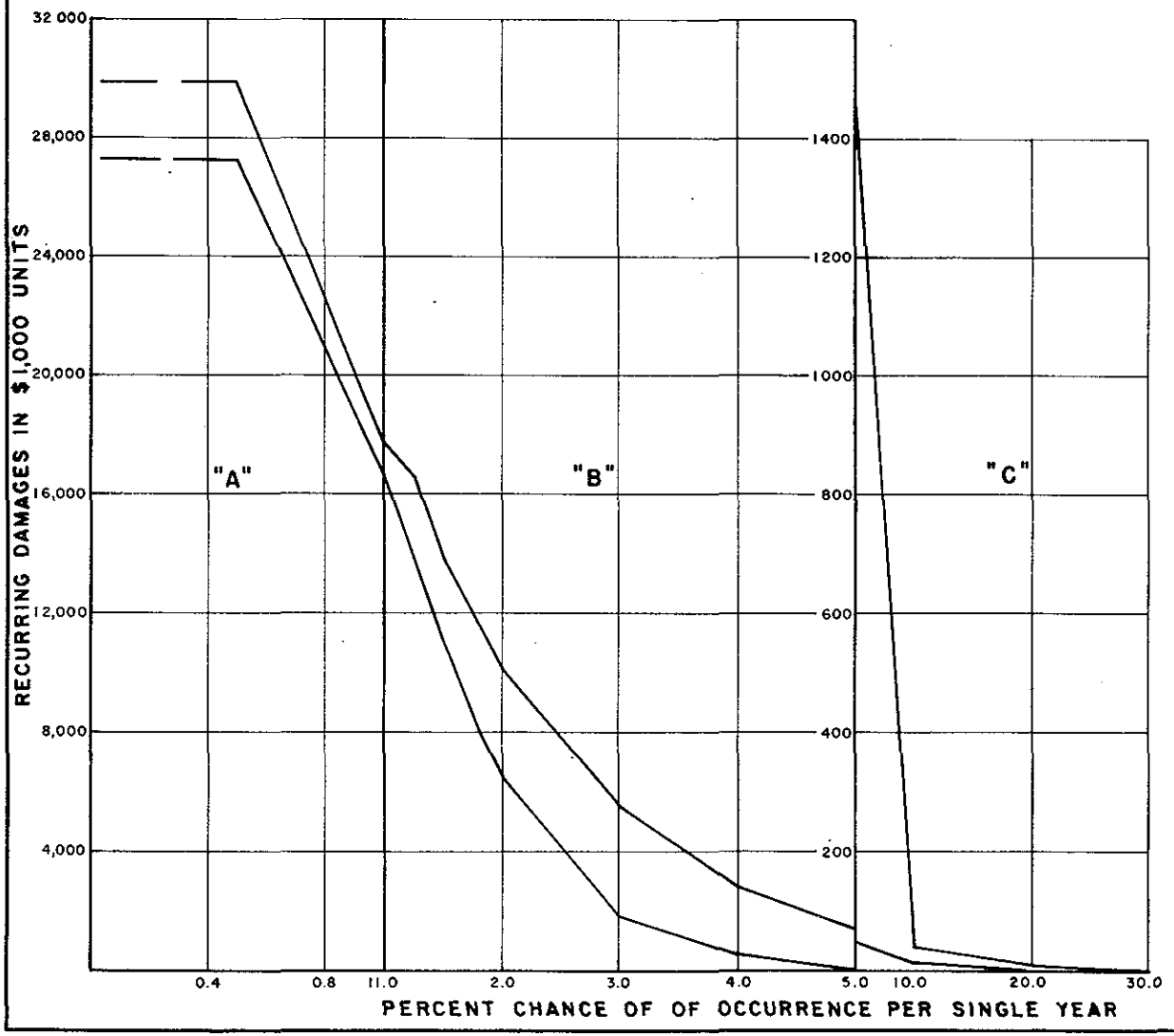
STAGE DAMAGE CURVE

NORTH NASHUA RIVER BASIN
ZONE 12
R. R. BRIDGE NO. 8 (U/S)
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL



	RANGE "A" 1" = $16,000			RANGE "B" 1" = $40,000			RANGE "C" 1" = $20,000			ANNUAL AVERAGE	
	AREA	LOSS	BEN	AREA	LOSS	BEN	AREA	LOSS	BEN	LOSSES	BENEFITS
NATURAL	15.12	241,920	24,320	4.23	169,200	108,400	0.13	2,600	39,400	413,720	172,120
FUTURE(P)	16.64	266,240		6.94	277,600		2.10	42,000		585,840	

1990 BEN

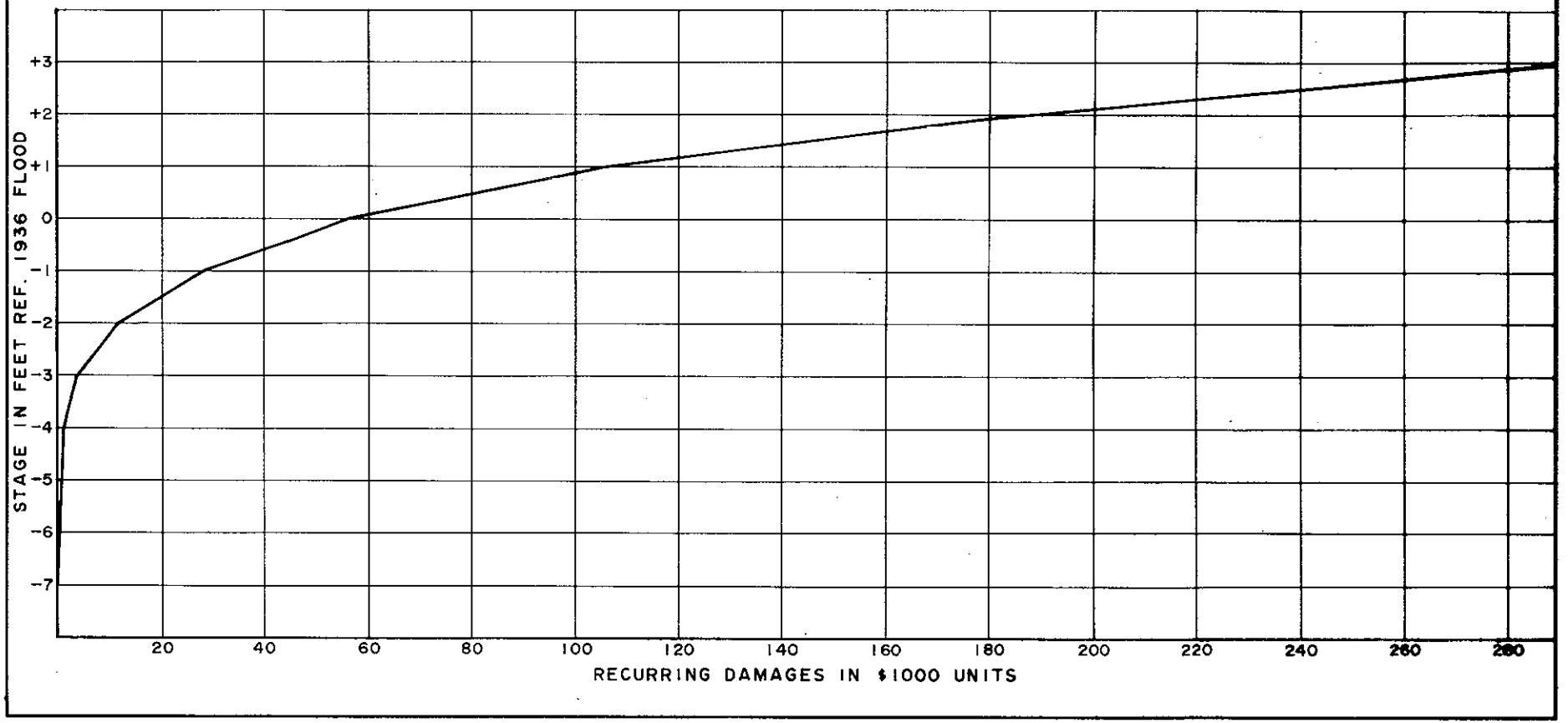


DAMAGE FREQUENCY CURVE

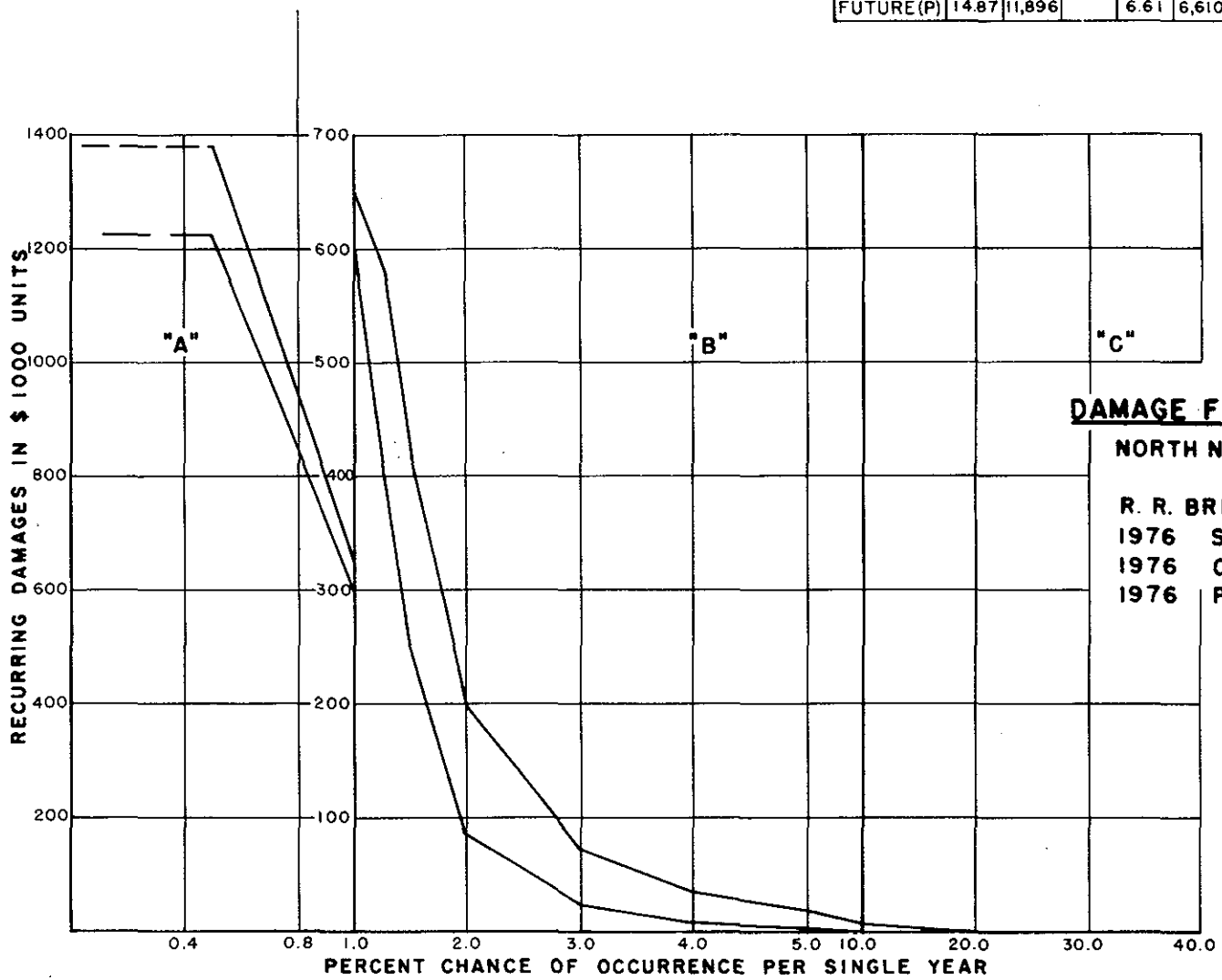
NORTH NASHUA RIVER BASIN
ZONE 12
R. R. BRIDGE NO. 8 (U/S)
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL

STAGE DAMAGE CURVE

NORTH NASHUA RIVER BASIN
ZONE 13
R.R. BRIDGE #8 (U/S)
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL



		RANGE "A" 1" = $ 800			RANGE "B" 1" = $ 1,000			RANGE "C" 1" = $ 10,000			ANNUAL AVERAGE	
		AREA	LOSS	BEN	AREA	LOSS	BEN	AREA	LOSS	BEN	LOSSES	BENEFITS
1990 BEN	NATURAL	13.20	10,560	1336	3.77	3,770	2,840	—	—	370	14,330.0	4546.0
	FUTURE(P)	14.87	11,896		6.61	6,610		.037	370		18,876.0	

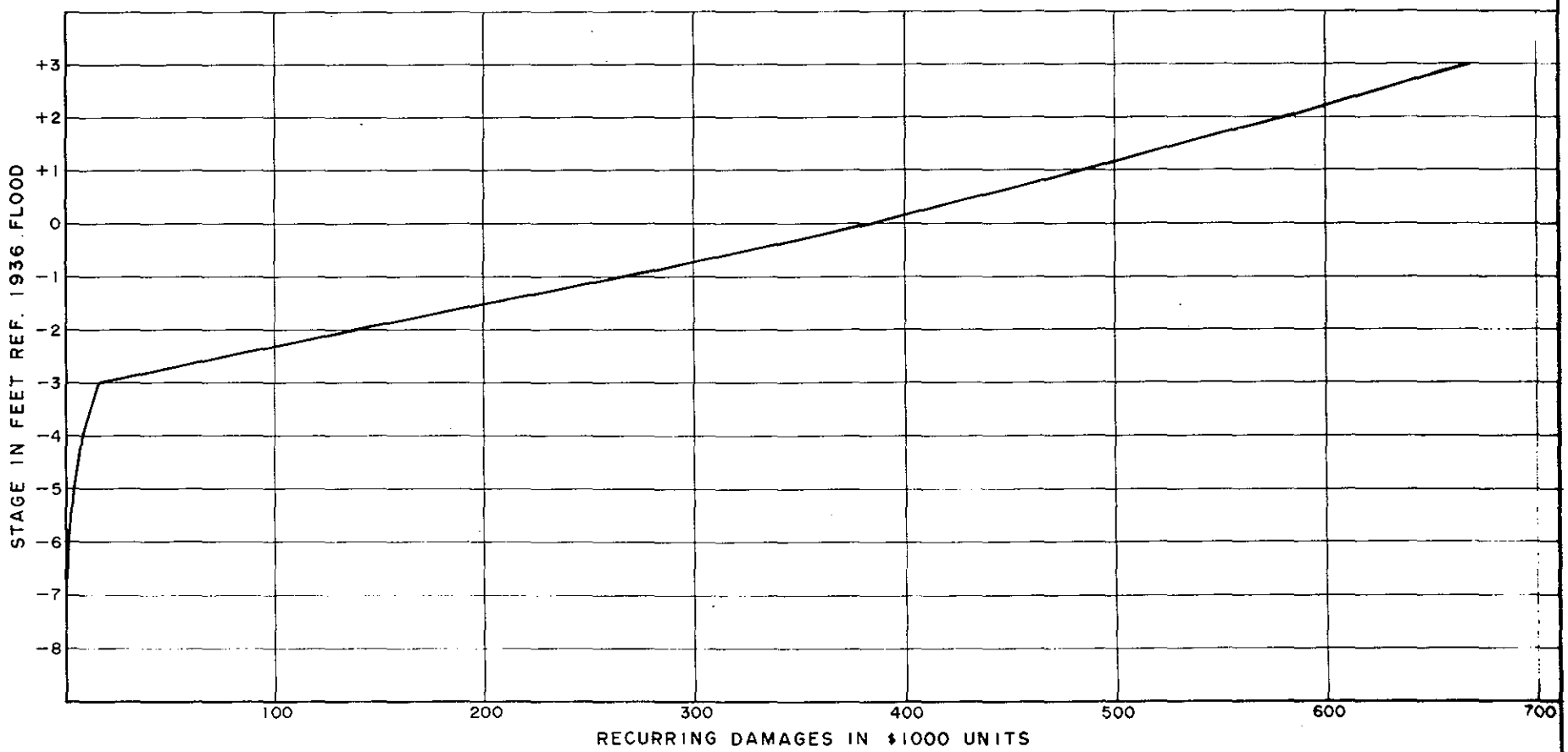


DAMAGE FREQUENCY CURVE

NORTH NASHUA RIVER BASIN
ZONE 13
R. R. BRIDGE NO. 8 (U/S)
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL

STAGE DAMAGE CURVE

NORTH NASHUA RIVER BASIN
ZONE 14
ROLLSTONE STREET BRIDGE (U/S)
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL



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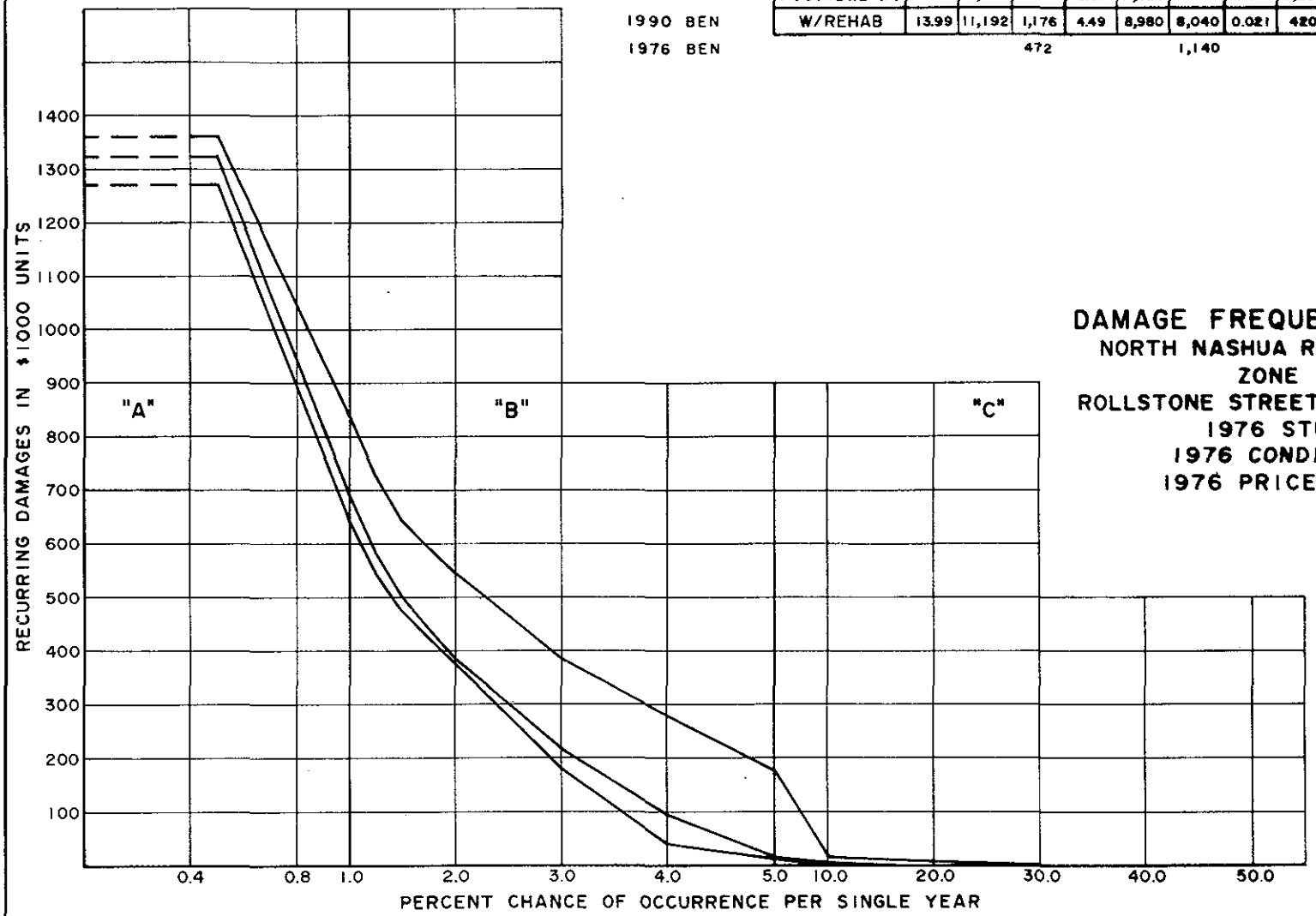
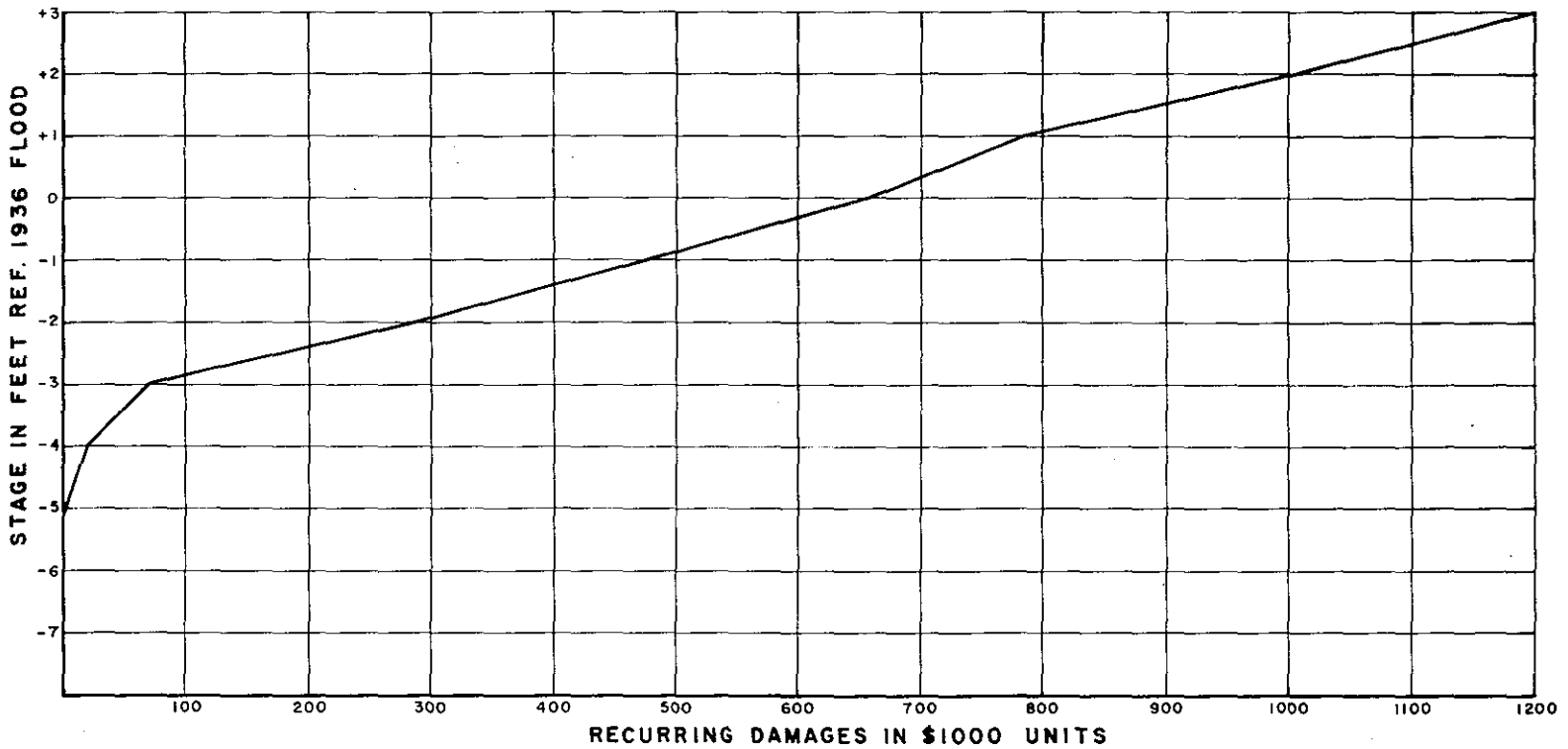
	AREA	LOSS	BEN	AREA	LOSS	BEN	AREA	LOSS	BEN	LOSSES	BENEFITS
NATURAL	14.58	11,664	704	5.06	10,120	6,900	0.031	620	5,580	22,404	13,184
POSSIBLE (F)	15.46	12,368	—	8.51	17,020	—	0.31	6,200	—	35,588	—
W/REHAB	13.99	11,192	1,176	4.49	8,980	8,040	0.021	420	5,780	20,592	14,996
1990 BEN			472			1,140			200		1,812
1976 BEN											



DAMAGE FREQUENCY CURVE
NORTH NASHUA RIVER BASIN
ZONE 14
ROLLSTONE STREET BRIDGE (U/S)
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL

STAGE DAMAGE CURVE

NORTH NASHUA RIVER BASIN
ZONE 15
LOWER RIVER STREET BRIDGE (U/S)
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL



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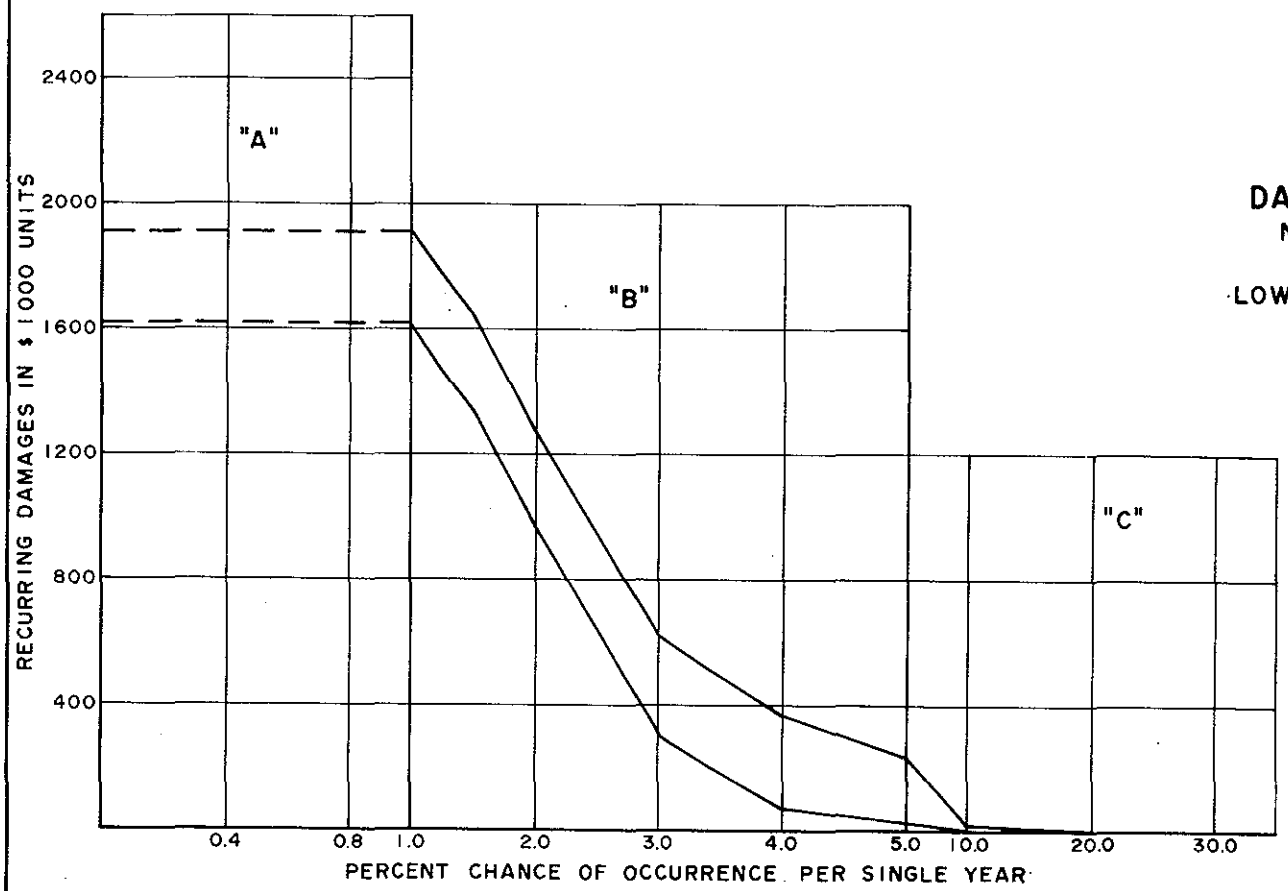
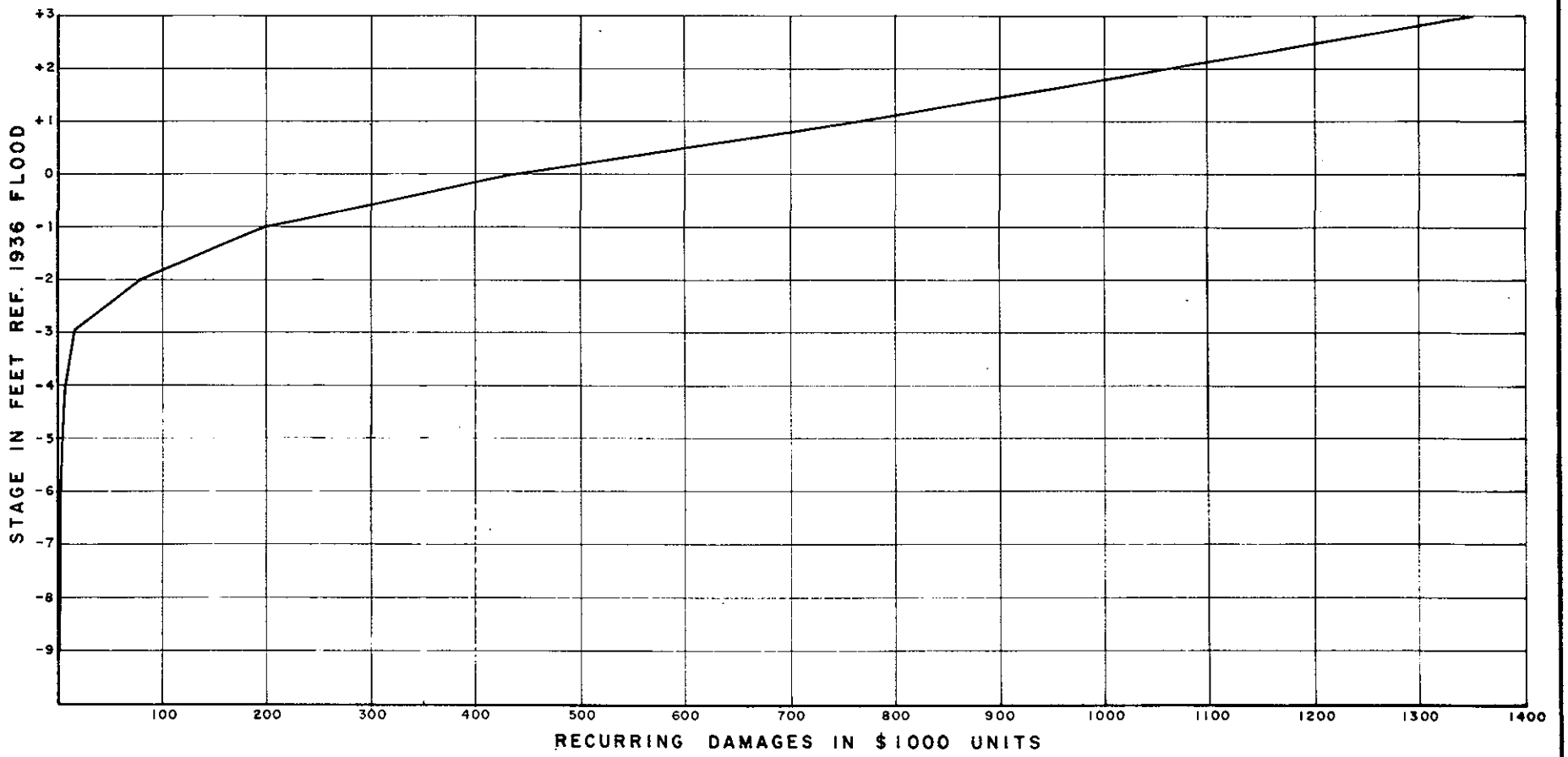
		AREA	LOSS	BEN	AREA	LOSS	BEN	AREA	LOSS	BEN	LOSSES	BENEFITS
1990 BEN	NATURAL	10.2	16,320	2,960	3.45	21,800	11,800	0.06	2,400	5,800	40,520	20,360
	P (FUTURE)	12.05	19,280	–	8.4	33,600	–	0.2	8,000	–	60,880	——

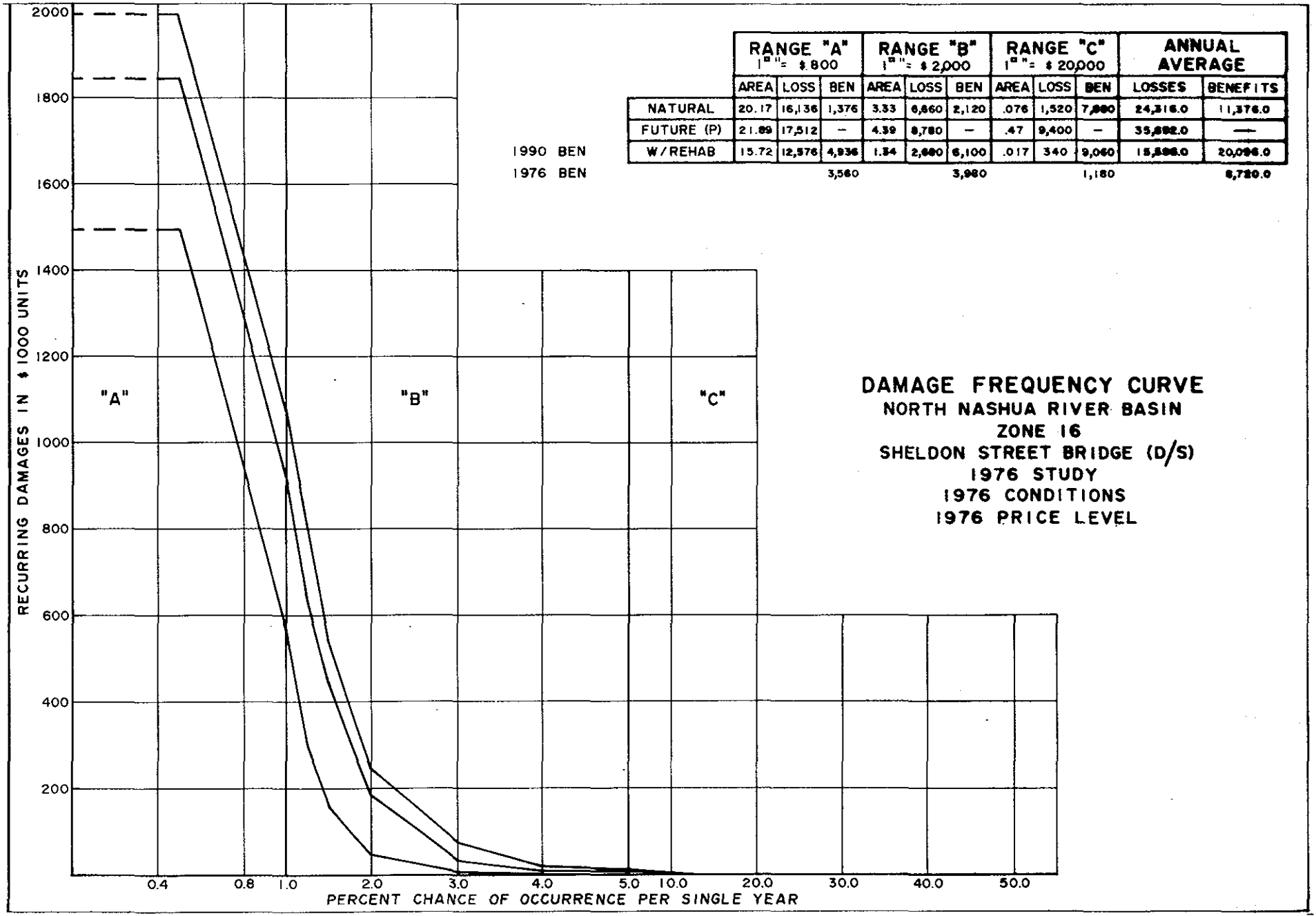


DAMAGE FREQUENCY CURVE
NORTH NASHUA RIVER BASIN
ZONE 15
LOWER RIVER STREET BRIDGE (U/S)
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL

STAGE DAMAGE CURVE

NORTH NASHUA RIVER BASIN
ZONE 16
SHELDON STREET BRIDGE (D/S)
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL



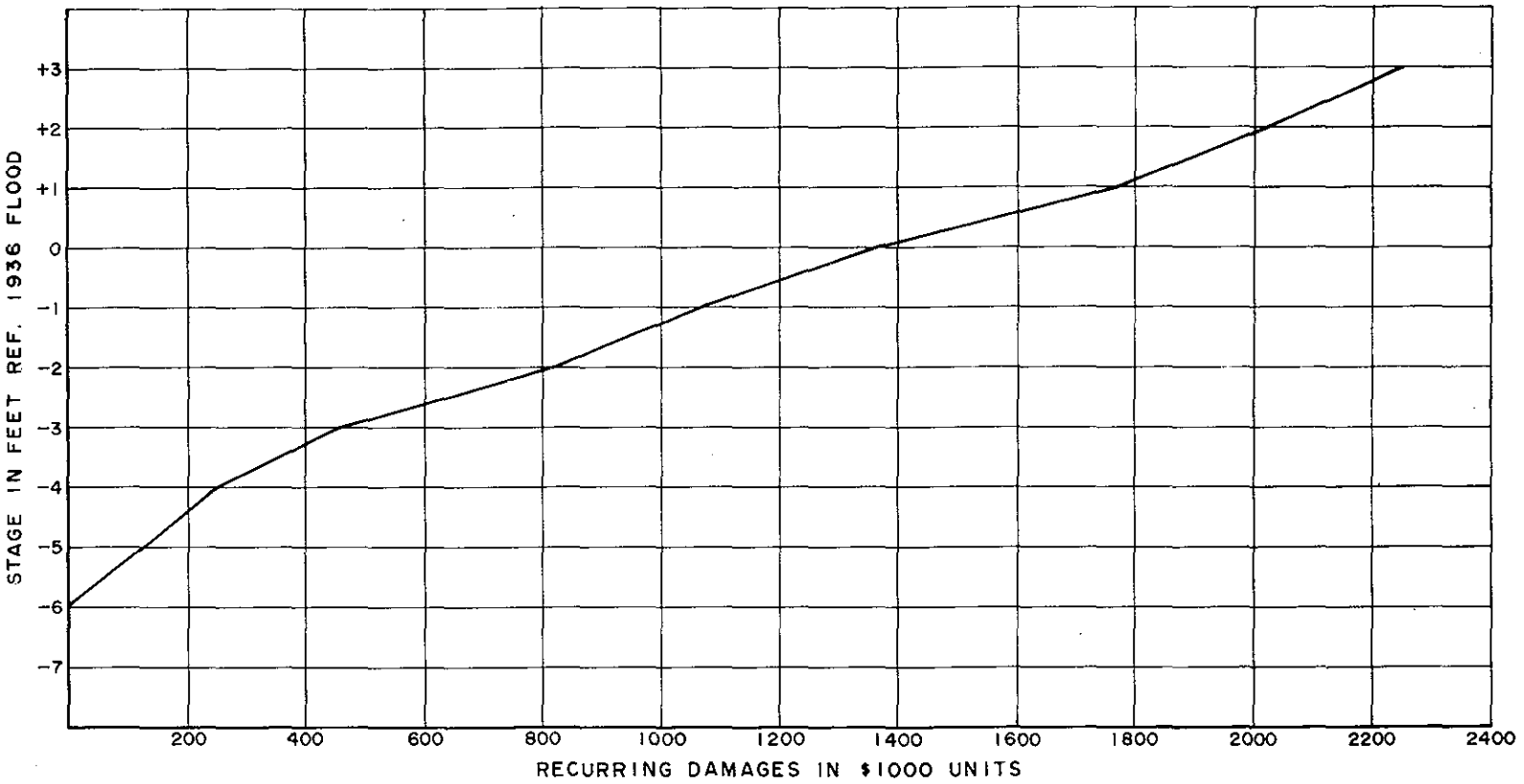


	RANGE "A" 1" = $ 800			RANGE "B" 1" = $ 2,000			RANGE "C" 1" = $ 20,000			ANNUAL AVERAGE	
	AREA	LOSS	BEN	AREA	LOSS	BEN	AREA	LOSS	BEN	LOSSES	BENEFITS
NATURAL	20.17	16,136	1,376	3.33	6,660	2,120	.076	1,520	7,880	24,316.0	11,376.0
FUTURE (P)	21.89	17,512	—	4.39	8,780	—	.47	9,400	—	35,692.0	—
W/REHAB	15.72	12,576	4,936	1.34	2,680	6,100	.017	340	9,060	15,596.0	20,096.0
1990 BEN			3,560			3,980			1,180		8,720.0
1976 BEN											

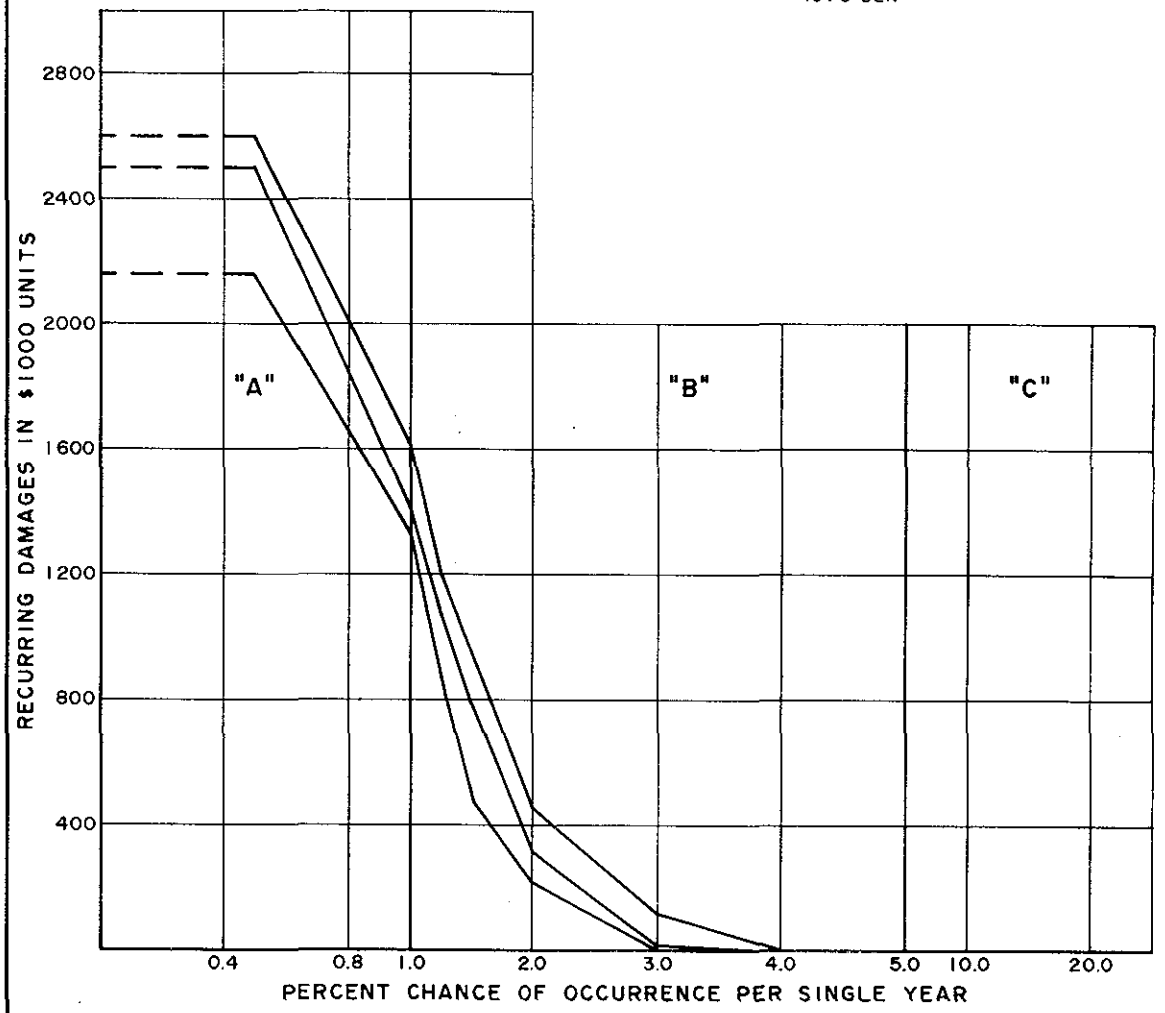
DAMAGE FREQUENCY CURVE
NORTH NASHUA RIVER BASIN
ZONE 16
SHELDON STREET BRIDGE (D/S)
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL

STAGE DAMAGE CURVE

NORTH NASHUA RIVER BASIN
ZONE 17
SHELDON STREET (U/S)
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL



		RANGE "A" 1" = $1,600			RANGE "B" 1" = $4,000			RANGE "C" 1" = $40,000			ANNUAL AVERAGE	
		AREA	LOSS	BEN	AREA	LOSS	BEN	AREA	LOSS	BEN	LOSSES	BENEFITS
	NATURAL	13.9	22,240	1,440	2.4	9,600	4,000	–	–	–	31,840	5,440
	P (FUTURE)	14.8	23,680	–	3.4	13,600		–	–	–	37,280	–
1990 BEN	W/REHAB	12.2	19,520	4,160	1.8	7,200	6,400	–	–	–	26,720	10,560
1976 BEN				2,720			2,400					5,120

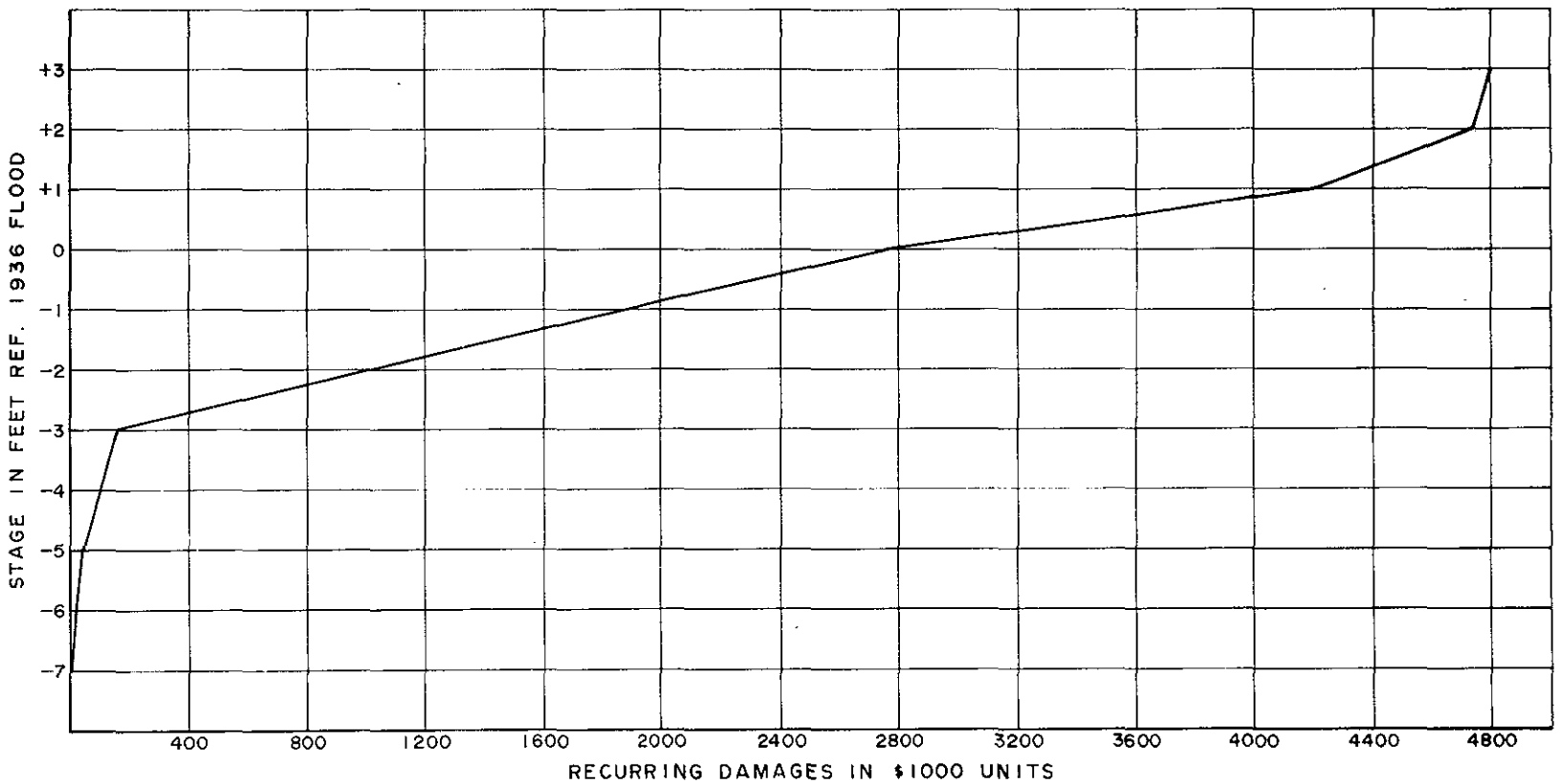


DAMAGE FREQUENCY CURVE

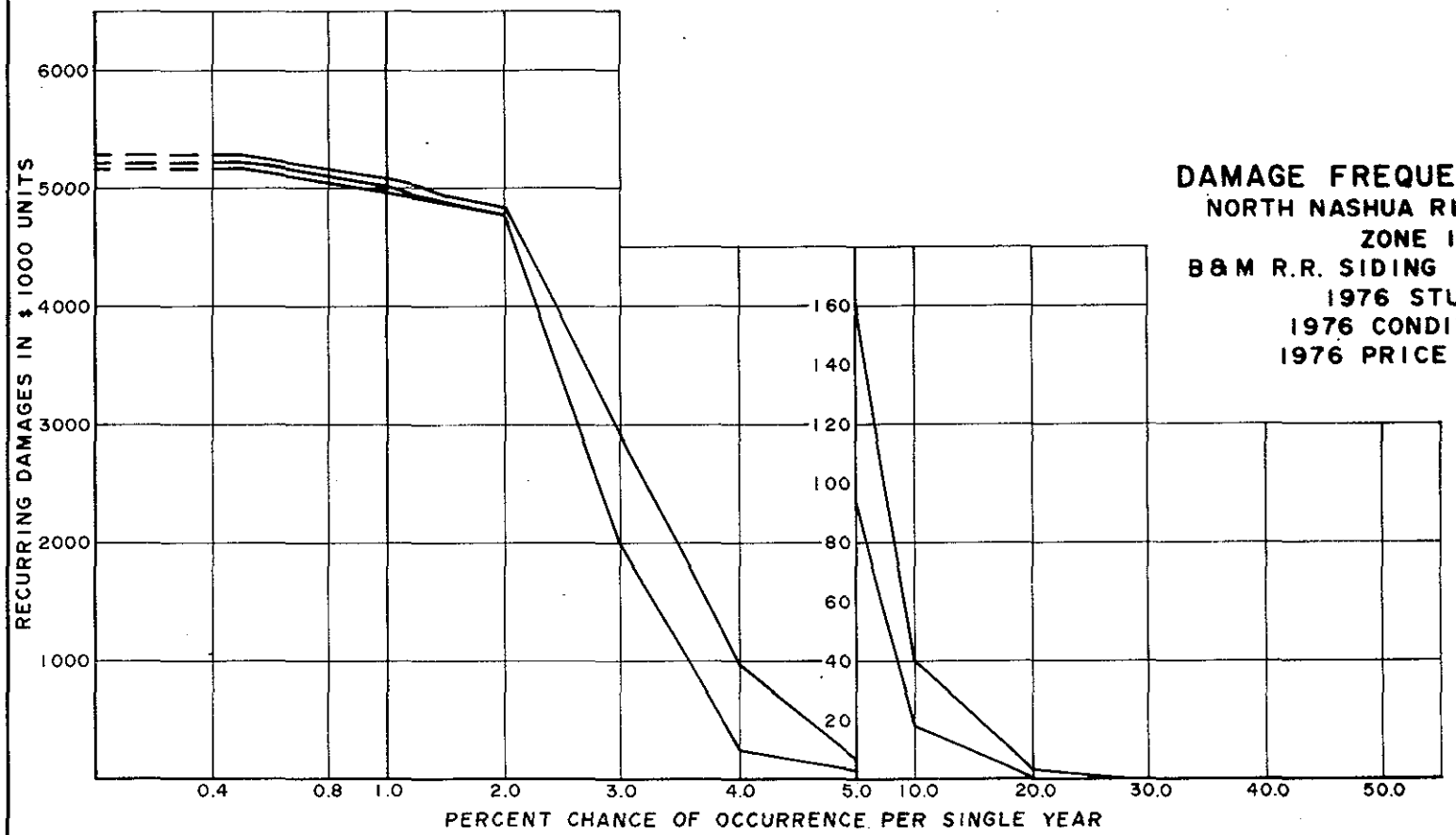
NORTH NASHUA RIVER BASIN
ZONE 17
SHELDON STREET (U/S)
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL

STAGE DAMAGE CURVE

NORTH NASHUA RIVER BASIN
ZONE 18
B&M R.R. SIDING BRIDGE (U/S)
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL



	RANGE "A" I"= $4,000			RANGE "B" I"= $10,000			RANGE "C" I"= $4,000			ANNUAL AVERAGE	
	AREA	LOSS	BEN	AREA	LOSS	BEN	AREA	LOSS	BEN	LOSSES	BENEFITS
NATURAL	12.95	51,800	280.0	9.61	96,100	16,800	.933	3,732	3,948	151,632.0	20,888.0
POSSIBLE (F)	13.02	52,080	—	11.27	112,700	—	1.92	7,680	—	172,460.0	—
W/REHAB	12.79	51,160	920.0	9.45	94,500	18,200	.933	3,732	3,948	149,392.0	23,068.0
1990 BEN											
1976 BEN			640.0			1,600			0		2,240.0



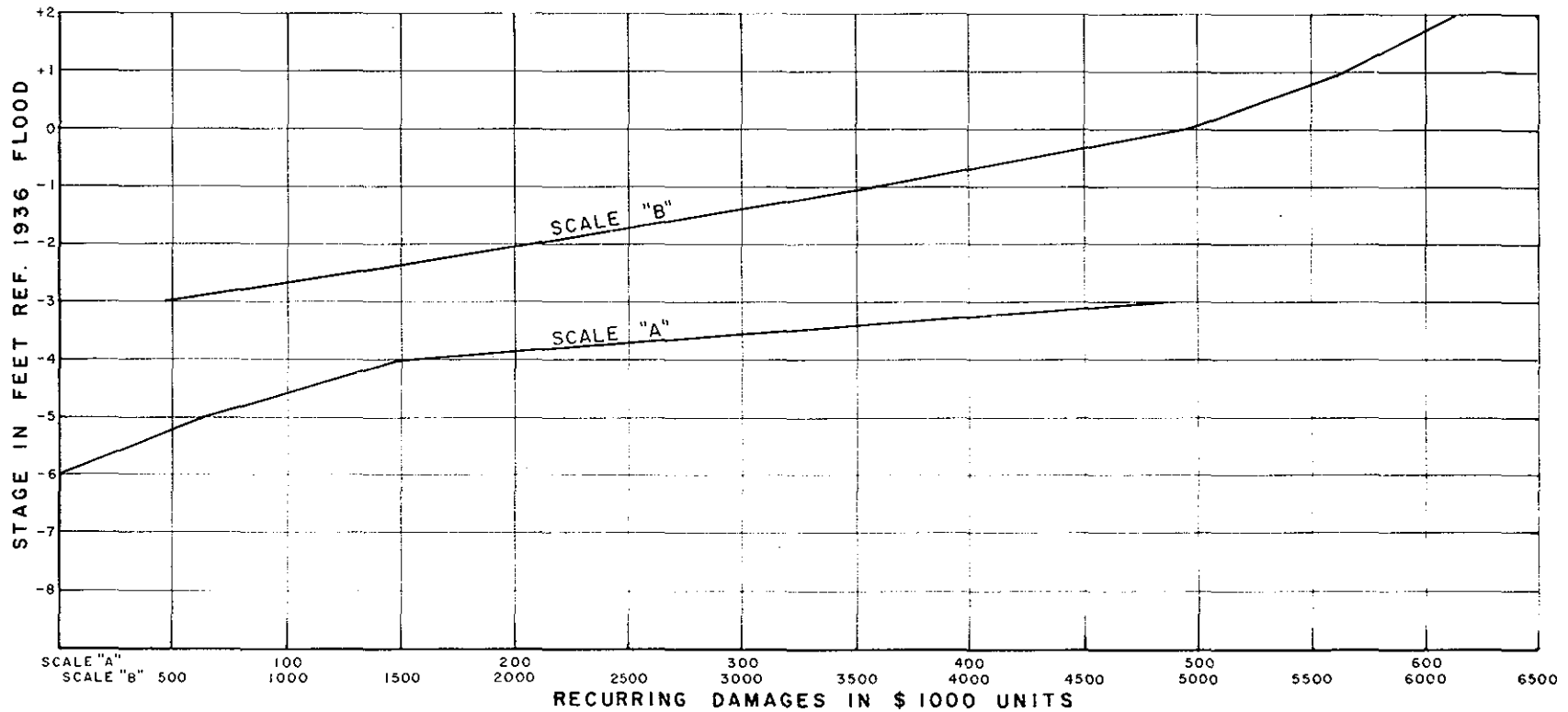
DAMAGE FREQUENCY CURVE

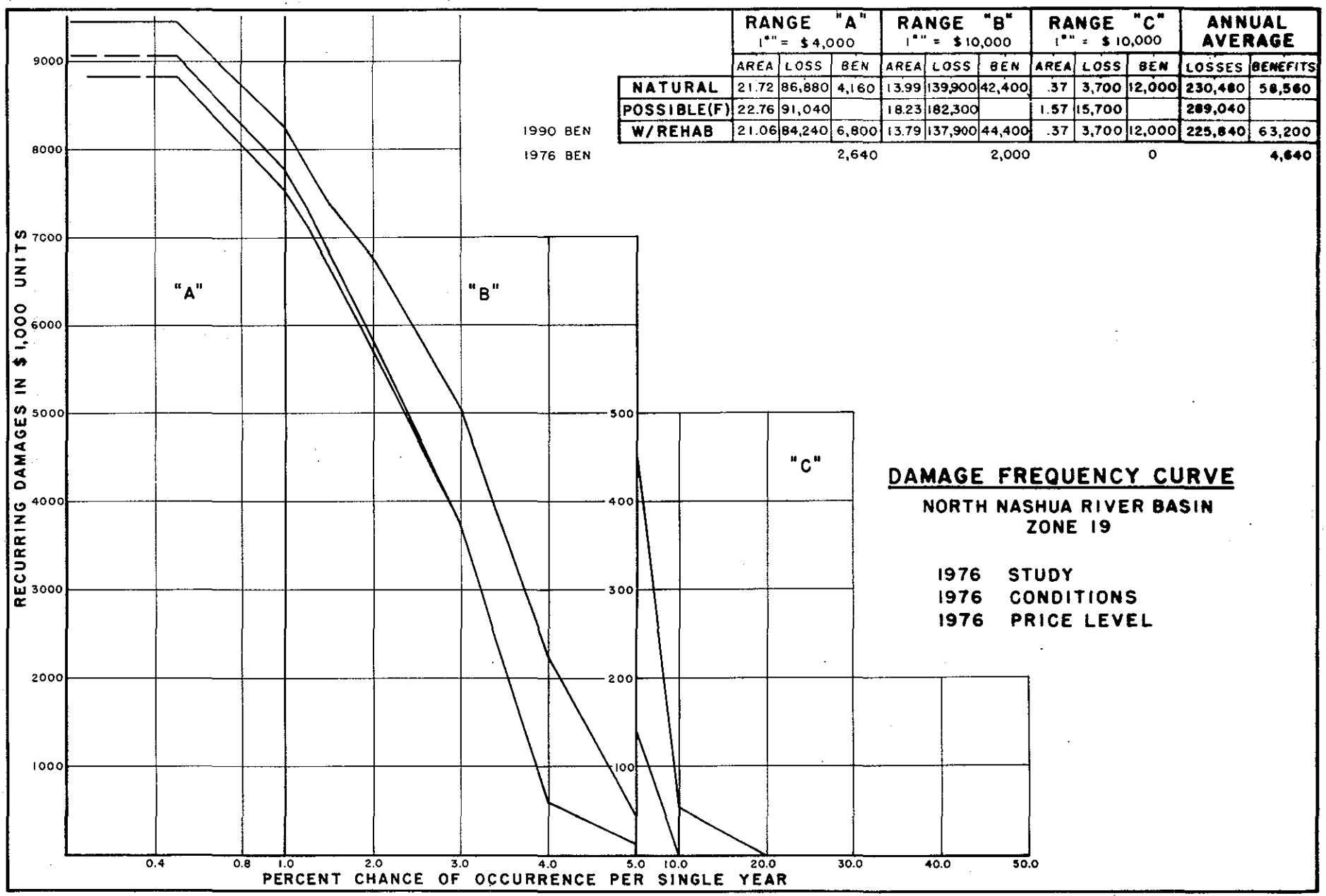
NORTH NASHUA RIVER BASIN
ZONE 18
B&M R.R. SIDING BRIDGE (U/S)
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL

STAGE DAMAGE CURVE

NORTH NASHUA RIVER BASIN
ZONE 19

1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL





	RANGE "A" 1" = $4,000			RANGE "B" 1" = $10,000			RANGE "C" 1" = $10,000			ANNUAL AVERAGE	
	AREA	LOSS	BEN	AREA	LOSS	BEN	AREA	LOSS	BEN	LOSSES	BENEFITS
NATURAL	21.72	86,880	4,160	13.99	139,900	42,400	.37	3,700	12,000	230,480	58,560
POSSIBLE(F)	22.76	91,040		18.23	182,300		1.57	15,700		289,040	
W/REHAB	21.06	84,240	6,800	13.79	137,900	44,400	.37	3,700	12,000	225,840	63,200
1990 BEN											
1976 BEN			2,640			2,000			0		4,640

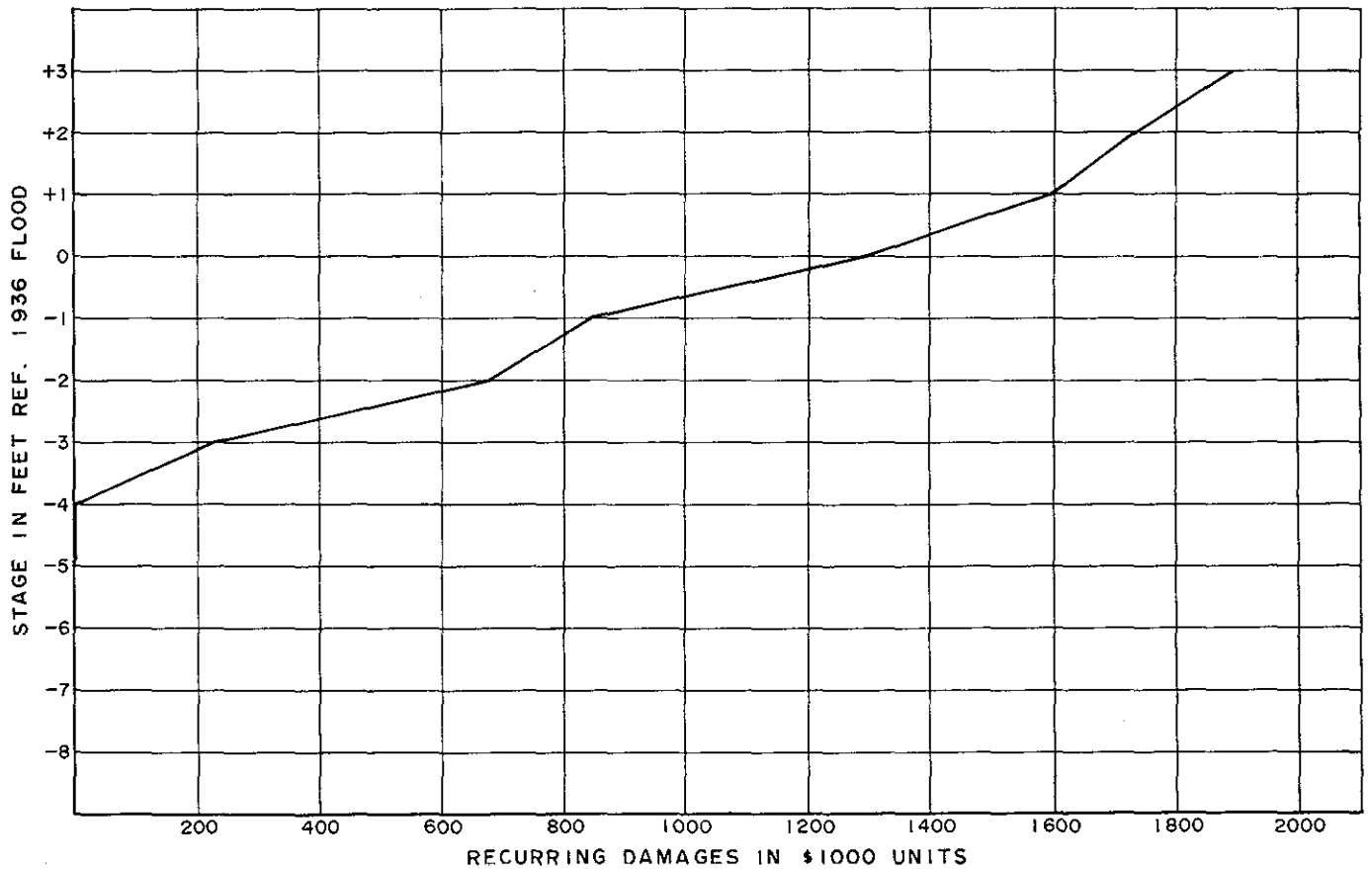
DAMAGE FREQUENCY CURVE

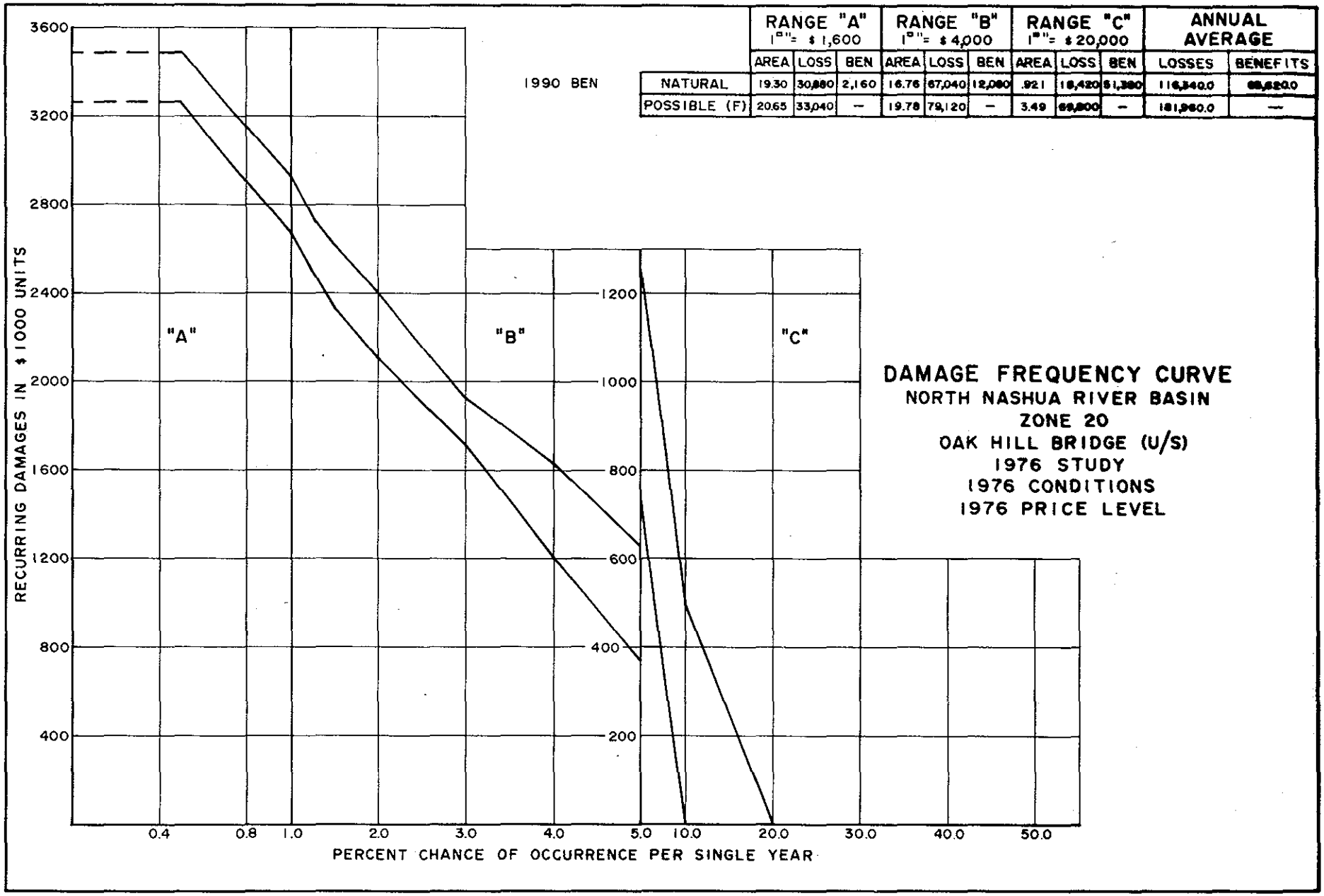
NORTH NASHUA RIVER BASIN
ZONE 19

1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL

STAGE DAMAGE CURVE

NORTH NASHUA RIVER BASIN
ZONE 20
OAK HILL BRIDGE (U/S)
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL





	RANGE "A" I"= $1,600			RANGE "B" I"= $4,000			RANGE "C" I"= $20,000			ANNUAL AVERAGE	
	AREA	LOSS	BEN	AREA	LOSS	BEN	AREA	LOSS	BEN	LOSSES	BENEFITS
NATURAL	19.30	30,880	2,160	16.76	67,040	12,080	.921	18,420	$1,380	116,340.0	65,620.0
POSSIBLE (F)	20.65	33,040	—	19.78	79,120	—	3.49	69,800	—	181,960.0	—

DAMAGE FREQUENCY CURVE

NORTH NASHUA RIVER BASIN
ZONE 20
OAK HILL BRIDGE (U/S)
1976 STUDY
1976 CONDITIONS
1976 PRICE LEVEL

APPENDICES

APPENDIX I

HYDROLOGIC ANALYSIS

APPENDIX I
HYDROLOGIC ANALYSIS
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NORTH NASHUA RIVER
CHANNEL REHABILITATION
FITCHBURG, MASSACHUSETTS

APPENDIX I
HYDROLOGIC ANALYSIS

1. INTRODUCTION

This appendix presents the hydrologic analysis pertinent to the design of the North Nashua River channel rehabilitation through Fitchburg, Massachusetts. Included are sections on general climatology, streamflow, analysis of floods and the hydraulics of the river channel.

Extensive improvements were made in the river channel through Fitchburg following the disastrous flood of March 1936. Improvements consisted of removal of dams, channel straightening and enlarging, plus the construction of retaining walls and revetments. The improved channel was designed to safely convey a flow equal in magnitude to the March 1936 flood. The improvements have since deteriorated and require rehabilitation in order to safely convey the original design flow. Such rehabilitation is a necessity to insure the integrity of any comprehensive flood control plan for the area and was therefore made an integral part of the flood control plan as set forth in the 1965 report, entitled: "Water Resources Development Plan, North Nashua River Basin". This appendix concerns only

the channel rehabilitation aspects of the flood control plan, as authorized in the Flood Control Act of 1966, Public Law 98-789.

2. BASIN DESCRIPTION

a. General. The North Nashua River has a total watershed area of 132 square miles at its confluence with the South Branch of the Nashua River in Lancaster, Massachusetts. The watershed is rectangular in shape with an approximate length of 21 miles in the northwest-southeast direction, and maximum width of about 11 miles. The topography of the upper portion of the watershed above Leominster is moderately steep and hilly, while the lower basin tends to have much milder slopes. The upper basin is largely forested and contains little tillable land. Elevations in the basin vary from about 230 feet msl at Lancaster, Massachusetts to a maximum of 2,006 feet msl at Wachusett Mountain on the periphery. The watershed contains numerous small lakes and ponds which are utilized for municipal water supply, limited hydroelectric power production, industrial water supply, and recreation. Most of these lakes provide little flood reduction during major storms due to limited surcharge storage capacity and/or smallness of drainage area controlled.

The drainage area of the North Nashua River at Arden Mill Dam in Fitchburg is about 63 square miles comprised mainly of the three tributaries: Whitman River, Flagg Brook and Phillips Brook. A listing of the contributing watersheds is shown in Table I-1, and a basin map is shown on Plate I-1.

TABLE I-1

NORTH NASHUA DRAINAGE AREAS
AT FITCHBURG, MASSACHUSETTS

Watershed	Area (sq. miles)	Percent
Whitman River	27.5	44
Flagg Brook	12.0	19
Phillips Brook	16.0	25
Local	8.0	12
Total at Fitchburg	63.5	100

b. Whitman River. The Whitman River, the largest tributary of the North Nashua River, has a drainage area of 27.5 square miles. The watershed contains several reservoirs which are used for limited hydroelectric power production and process water storage by the paper industries in Fitchburg. From its source at Lake Wampanoag to its confluence with the North Nashua River, the Whitman River falls about 495 feet with an average slope over its 8.6 miles of length of 58 feet per mile.

c. Flagg Brook. Flagg Brook has a drainage area of 12 square miles, much of which has been developed for municipal and industrial water supply and private recreational uses. The watershed is hilly and largely forest-covered and includes the northerly slopes of Wachusett Mountain which has a maximum elevation of about 2,000 feet msl. Except for this extreme elevation, the watershed generally rises to averages from 650 to 1,000 feet msl, about 200 to 400 feet above the streambed. The average slope of Flagg Brook, including its

longest tributary, is about 46 feet per mile between Wachusett Lake and its confluence with the Whitman River, a distance of 6.5 miles. Peak flood discharges from Flagg Brook are lagged and attenuated to some extent by reservoir surcharge storages in the watershed.

d. Phillips Brook. Phillips Brook rises in the town of Ashburnham, Worcester County, Massachusetts at the outlet of Winnekeag Lake. It has a drainage area of 15.9 square miles and joins the North Nashua River near the community of West Fitchburg. Except for Winnekeag Lake with a drainage area of 2.2 square miles, only minor industrial water supply and limited hydroelectric power storage facilities have been developed. The small reservoirs serving these purposes do not substantially modify moderate and major floodflows. The average channel slope is about 70 feet per mile over its nine miles of length.

3. CLIMATOLOGY

a. General. The North Nashua River basin has a variable climate and frequently experiences periods of heavy precipitation produced by local thunderstorms and larger weather systems of tropical and extra-tropical origin. The basin lies in the path of the prevailing "westerlies" which traverse the country in an easterly or northeasterly direction and produce frequent weather changes. Temperature extremes within the basin range from summer-time highs of about 100° Fahrenheit to sub-zero temperatures in the minus teens occurring for short periods in the winter.

b. Temperature. The mean annual temperature in the North Nashua River watershed is about 48° F. Recorded temperature extremes at Fitchburg vary from a maximum of 105° F to a minimum of -21° F. Freezing temperatures may be expected from late September to late April. Table I-2 lists the mean, maximum and minimum monthly and annual temperatures at Fitchburg for 89 years of record through 1975.

TABLE I-2

MONTHLY TEMPERATURES AT FITCHBURG, MASSACHUSETTS
(Degrees Fahrenheit)

Month	Average	Instantaneous Maximum	Instantaneous Minimum
January	24.8	68	-21
February	25.0	68	-21
March	34.5	86	-8
April	46.0	92	6
May	57.7	97	26
June	66.4	100	35
July	71.6	103	40
August	69.3	105	35
September	62.1	101	27
October	51.3	91	16
November	39.9	81	-2
December	28.6	71	-16
Annual	48.1		

c. Precipitation. The average annual precipitation over the North Nashua River Basin is approximately 43 inches, uniformly distributed throughout the year. The maximum and minimum annual precipitation at Fitchburg are 60.23 and 27.45 inches, respectively. Table I-3 lists the mean, maximum and minimum monthly and annual precipitation at Fitchburg for 111 years of record, through 1975.

TABLE I-3

MONTHLY PRECIPITATION AT
FITCHBURG, MASSACHUSETTS
(In Inches)

Month	Mean	Maximum	Minimum
January	3.44	7.78	0.84
February	3.28	8.33	0.34
March	3.67	12.15	Trace
April	3.42	9.91	0.57
May	3.57	8.25	0.57
June	3.66	11.56	0.09
July	3.67	12.68	0.46
August	3.66	10.72	0.17
September	3.64	14.04	0.19
October	3.43	13.01	Trace
November	3.84	7.79	0.38
December	3.51	9.33	0.58
Annual	42.77	60.23	27.45

d. Snow Fall. The annual snowfall in the basin averages about 62 inches at Fitchburg, located at about elevation 400 feet msl. Table I-4 gives the mean monthly and annual snowfall at Fitchburg for 90 years of record, through 1975.

TABLE I-4

SNOWFALL DATA AT
FITCHBURG, MASSACHUSETTS
(Depth in Inches)

Month	Mean
January	15.6
February	17.6
March	11.3
April	2.5
May	Trace
June	-
July	-
August	-
September	-
October	Trace
November	3.5
December	11.7
Annual	62.2

e. Snow Cover. Snow surveys have been taken in or adjacent to the North Nashua River watershed since 1950. These surveys indicate that the water content of the snow normally reaches a maximum about the first of March. The recorded mean, maximum and minimum average basin water content of the snow for the nearby Millers River basin for 27 years of record through 1976 is given in Table I-5.

TABLE I-5

WATER EQUIVALENT IN SNOW COVER
MILLERS RIVER WATERSHED

1950 - 1976
(inches)

	Mean	Maximum	Minimum
1 February	2.1	4.2	0.3
15 February	2.7	5.6	0.0
1 March	3.1	7.6	0.0
15 March	3.2	7.7	0.0
1 April	2.0	8.2	0.0
15 April	0.3	4.9	0.0

4. STORMS

a. General. The North Nashua River basin experiences storms of four general types, namely:

(1) Extra-tropical continental storms which move across the basin under the influence of the prevailing "westerlies".

(2) Extra-tropical maritime storms which originate and move northward along the eastern coast of the United States.

(3) Storms of tropical origin, some of which attain hurricane magnitude.

(4) Thunderstorms produced by local convective activity or by more general frontal action.

The most severe storms in southern and central New England have been of tropical origin which occur during the late summer and early autumn.

5. STREAMFLOW

The U.S. Geological Survey (USGS) has maintained a continuous record of streamflow on the North Nashua River in Leominster since September 1935. The drainage area of the river at the site of this gage is 107 square miles and the long-term average flow is 193 cfs, equivalent to an annual runoff from the watershed of 24.7 inches, or 58 percent of annual precipitation. The annual runoff has varied from a maximum of 307 cfs in 1956, to a minimum of 81 cfs in 1965. Table I-6 presents a summary of maximum, minimum and mean monthly flows for the period of record at Leominster.

The Geological Survey has also maintained a short-term gaging station on the North Nashua River at Fitchburg since October 1972. The drainage area of the river at this gage site is 63.7 square miles and during the short period of record (1972-1974) the maximum recorded flow was 2,080 cfs, occurring on 21 December 1973. The average flow of 133 cfs, represents an annual runoff of 28.6 inches from the contributing watershed.

TABLE I-6

ANNUAL RUNOFF
NORTH NASHUA RIVER NEAR LEOMINSTER

Drainage area = 107 square miles
(cubic feet per second)

Month	Average		Maximum		Minimum	
	(cfs)	(inches)	(cfs)	(inches)	(cfs)	(inches)
January	205.5	2.23	465	5.05	50.9	0.55
February	215.7	2.12	534	5.24	88.8	0.87
March	372.8	4.05	1289	14.00	140.0	1.52
April	422.5	4.44	868	9.13	154.0	1.62
May	242.7	2.64	450	4.89	85.4	0.93
June	155.5	1.63	393	4.13	64.3	0.68
July	91.1	0.99	392	4.26	42.9	0.47
August	75.1	0.82	286	3.11	38.1	0.41
September	90.6	0.95	595	6.26	38.9	0.41
October	95.8	1.04	606	6.58	39.4	0.43
November	155.6	1.64	485	5.10	44.4	0.62
December	190.8	2.07	429	4.66	58.6	0.64
Annual	192.8	24.66	307	39.27	81.2	10.39

6. ANALYSIS OF FLOODS

a. General. Since flow records have been maintained, the North Nashua has experienced three notable high flows. These occurred in March 1936, September 1938 and October 1955. All three high flows were generally produced by about 4 to 6 inches of rainfall in about a 24-hour period. The North Nashua basin was fortunate in narrowly escaping the heavy rainfall of up to 12 inches that occurred in nearby basins during the September 1938 and August 1955 storm events.

Peak flows through Fitchburg are produced by the combined runoff from Flagg Brook, Whitman River, Phillips Brook and the 8.0 square mile local area. Though peak flows from the tributaries are not exactly coincident, they are sufficiently close so that they all contribute significantly to the resulting peak flow through Fitchburg. An analysis of the development of past high flows at Fitchburg is graphically illustrated on Plate I-2. Peak discharges in Fitchburg were based largely on computations of flow over existing dams.

b. March 1936 Flood. The greatest recorded flow on the North Nashua at the Leominster gage was 16,300 cfs and occurred as the result of the second storm during March 1936. Intermittent periods of moderate to heavy rainfall during the month, combined with considerable snowmelt, produced two distinct high flows. The first rise, occurring on the 12th, was largely the result of runoff from melting snow with some contribution from moderate rainfall which averaged about 3 inches over the basin during the period 9-13 March. A second storm period, between the 16th and 19th, produced the record flow on the North Nashua River. This second peak resulted from intense rainfall, which averaged about 5.5 inches, with only minor contribution from snowmelt. The 1936 flood development is graphically illustrated on Plate I-2 and comparative rainfall data is shown in Table I-7.The peak discharge at Fitchburg was computed to be about 9,400 cfs at Arden Mill Dam.

TABLE I-7

MAXIMUM RAINFALL - DURATION DATA
(Inches)

Storm	1 hr	2 hr	3 hr	6 hr	12 hr	24 hr
March 1936 (Worcester)	0.8	1.0	1.4	2.3	4.1	5.3
Sep 1938 (Worcester)	0.7	1.0	1.3	2.1	2.6	3.8
Oct 1955 (Sterling)	0.5	0.8	1.0	1.7	3.1	4.6
June 1944 (Fitchburg)	1.8	2.3	2.6	3.3	3.9	4.7
100-yr. freq.	2.6	3.4	3.7	4.6	5.4	6.3
Standard Project	3.2	4.5	5.7	8.4	9.7	11.0

c. September 1938 Flood. Another high flow producing event occurred as a result of rainfall associated with the September 1938 hurricane that passed up the Connecticut River valley. The North Nashua basin narrowly missed the brunt of this storm with rainfall amounts of 14 inches occurring a short distance to the west. Rainfall averaged about 7 inches on 18-21 September in the North Nashua basin, with about 4 inches falling in a 24-hour period on the 20th. The resulting peak flow at the Leominster gage was 10,300 cfs and the computed peak flow over Arden Mill Dam in Fitchburg was about 8,900 cfs.

d. October 1955 Flood. The North Nashua watershed escaped the widespread torrential hurricane rainfall of August 1955, but did experience high flow producing rainfall in October 1955. The October storm resulted from the interaction of a west to east frontal weather system with a coastal low pressure system moving northward. Rainfall in the watershed amounted to about 5 inches in 24 hours on the 15th, based on rainfall records at Sterling, Massachusetts. Total storm rainfall was in the order of 7 inches.

The peak flow of the river at Leominster, as recorded at the gage, was 8,870 cfs. The peak flow at Fitchburg, based on high water data, was estimated to be about 7,800 cfs.

Peak flows for the three floods of record both at Leominster, and at Fitchburg, are summarized in Table I-8.

e. June 1944 Flood. The fourth highest flow of record at Leominster gage occurred on the 25th of June 1944 and resulted from intense rainfall accompanying severe thunderstorms. Rainfall in the area totaled about 5.7 inches in a 24-hour period. The peak flow resulting at Fitchburg is not known.

TABLE I-8

PEAK FLOWS, NORTH NASHUA RIVER

Location	Fitchburg		Leominster		
Drainage Area, sq. miles	63.7		107		
Date	Peak Discharges (cfs)	(csm)	(cfs)	(csm)	Runoff (inches)
18 Mar 1936	9,400	149	16,300	152	4.0
21 Sep 1938	8,900	141	10,300	96	4.7
15 Oct 1955	7,800	124	8,870	83	5.0
25 Jun 1944	-	-	8,100	76	-
12 Mar 1936	-	-	5,500	51	-

7. PEAK DISCHARGE FREQUENCIES

A peak discharge frequency curve was developed for the North Nashua River at Fitchburg by relating the computed frequency statistics of the flow records for the North Nashua River at Leominster through comparison of common flood events at the two locations. The frequency curve at Leominster was developed by statistical analysis of the annual peak flows using a Log Pearson Type III distribution in accordance with procedures set forth in Water Resources Bulletin #17. The computed mean log, standard deviation and adopted skew for the North Nashua River at Leominster, with a drainage area of 107 square miles was 3.3634, 0.3033, and 0.8, respectively. The adopted parameters for the river at Fitchburg, with a drainage area of 63 square miles was: mean log = 3.3000, standard deviation = 0.3033, and adopted skew = 0.8. The peak flow data used in the statistical frequency analysis is listed in Table I-9. The developed frequency curves are shown on Plate I-3.

TABLE I-9

RECORDED PEAK FLOWS

Year	Leominster*	Fitchburg**	Year	Leominster*	Fitchburg**
1936	16,300	9,400	1956	8,870	7,800
1937	2,570		1957	1,730	
1938	10,300	8,900	1958	2,230	
1939	1,180		1959	3,560	
1940	2,380		1960	3,260	
1941	1,080		1961	1,660	
1942	2,960		1962	3,560	
1943	1,200		1963	2,330	
1944	8,100		1964	1,300	
1945	1,010		1965	1,260	
1946	1,600		1966	741	
1947	1,080		1967	1,551	
1948	1,800		1968	4,070	
1949	1,120		1969	2,140	
1950	1,070		1970	3,410	
1951	4,390		1971	1,140	
1952	2,140		1972	1,420	
1953	3,220		1973	1,940	1,170
1954	5,800		1974	2,610	2,080
1955	2,510		1975	2,190	1,670

*DA = 107 sq. mi.
**DA = 63.6 sq. mi.

During preauthorization studies in 1965, statistical parameters for determining flow frequencies at Fitchburg were developed by correlating the few historic flood peaks at Fitchburg with the gage record at Leominster. However, since 1973 a gage has been in operation at Fitchburg and in present studies the few years of flow records were combined with the historic peak flows and correlated with the Leominster record. These more

recent studies indicated little change in the statistical parameters as developed in the original studies, therefore, the frequency information presented in the 1965 authorizing survey report was generally retained.

8. STANDARD PROJECT FLOOD

The standard project flood for the North Nashua at Fitchburg was developed in 1965 in concert with the comprehensive flood control plan for the basin. The flood was developed by applying the standard project storm rainfall to an adopted unit hydrograph. This unit graph has since been verified in current studies through analysis of the December 1973 storm runoff recorded at the newly installed gaging station at Fitchburg.

The standard project storm had a 24-hour rainfall of 11.0 inches and produced a peak flow of 20,000 cfs on the river at Fitchburg. With the originally proposed Whitmanville, Nookagee and Phillips reservoirs, the standard project flood would be reduced to 8,900 cfs. The development of the standard project flood for Fitchburg is illustrated on Plate 1-4.

9. DESIGN DISCHARGE

The planned channel rehabilitation project will basically restore the integrity of the channel to its original design capacity of about 9,000 cfs which is nearly equivalent to the discharge of the March 1936 flood of record. Investigations have been made into increasing or supplementing channel capacity, but such plans would be very costly and disruptive due to required structural modifications or replacement of bridges, buildings and retaining walls and was considered impractical and uneconomical. With the system of flood control reservoirs, as proposed in the 1965 comprehensive plan, the standard project flood

at Fitchburg would be reduced from 20,000 cfs to about 9,000 cfs. Therefore, the rehabilitated channel, with 9,000 cfs capacity, would be adequate for standard project protection, when considered as one component in an overall comprehensive plan for flood control. If the reservoirs are not built then this project will serve to rehabilitate the channel to its original post 1936 design capacity.

10. HYDRAULIC EFFECTS OF CHANNEL REHABILITATION

The channel improvement project through Fitchburg, undertaken following the flood of 1936, extended approximately five miles from Cowees Mill Dam (since removed) upstream of Oak Hill Rd. down to the Fitchburg-Leominster town line. Improvements consisted of the removal of several old dams, channel enlargement and the construction of concrete cribwalls, dikes and riprap revetments. Rehabilitation will consist mainly of the repair of cribwalls, the replacement or reinforcement of riprap and the removal of some debris and vegetative growth. Such rehabilitative work will not markedly change the hydraulic character of the channel but is required to insure the overall integrity of the channel. Under present deteriorated conditions, it is considered that structural failures would occur at localized areas during flood events of less than design magnitudes. The location and extent of such failures is quite indeterminate, however, in the past when some localized failures appeared, emergency measures consisted of dumping rock on the riverward side of the walls to provide reinforcement. Such emergency

measures do encroach on the hydraulic capacity of the channel and it was concluded that if the project were not rehabilitated, then the deteriorating cribwalls would be replaced in the future with dumped rock placed on about a 1 to 1.5 slope. Such encroachment on the channel would increase design flood levels from 1.0 to 3 feet depending on location. In analyzing the benefits of the proposed rehabilitation work, it was assumed that such an increase in flood profiles would be prevented and the integrity of the existing project insured to design capacity by the proposed works.

11. WATER SURFACE PROFILES

Water surface profiles were computed with the aid of the computer backwater program HEC-2, developed by the Corps' Hydrologic Engineering Center in Davis, California.

Representative cross sections of the river are shown on plate I-5. Computations were made using Manning's "n" of from 0.030 to 0.045 for the channel sections and 0.08 for overbank areas. Allowance was made for obstructions in the overbank areas in the selection of the "n" value. Coefficients of contraction and expansion were set at 0.3 and 0.5, respectively. Computed profiles are shown on Plate I-6.

It is noted that the river reach through Fitchburg is quite steep and, though the flood profiles are not highly influenced by any one obstruction, the backwater profiles are influenced by numerous contractions which create a local hydraulic control causing the flow to approach "critical" conditions hydraulically.

Computed profiles are shown on Plate I-6 and in the attached supplemental Flood Plain Information Report.

12. VELOCITIES

Due to the steepness of the channel through the city, and the many constrictions present, design flow velocities in the channel are generally 10-12 fps. Pertinent hydraulic data, including depth of flow and velocities, is illustrated on Plate I-6.

Computed velocities and depth of flow at selected stations, particularly where rehabilitative work will be performed are listed in Table I-11.

13. BRIDGE CROSSINGS

There are a total of 22 highway and railroad bridges crossing the North Nashua (plus one building built over the river) within the reach to be rehabilitated in Fitchburg.

The restriction and resulting hydraulic loss posed by these structures range from negligible to moderately severe. However, because of the general steepness of the river channel the added backwater created by the more restrictive bridges is quite local in extent.

The bridges in the study reach, their effective cross-sectional flow area under design flow and the resulting hydraulic energy loss are listed in Table I-10. Relative locations and low chord elevations of the bridges are illustrated on Plate I-6. Table I-11 provides pertinent hydrologic data.

TABLE I-10

HYDRAULIC CHARACTERISTICS OF BRIDGES

Station (1)	Name (Bridge or Structure)	Type	Length (ft)	Elevations (ft msl) (2) Low Chord	T.O.R.	Channel	(Area (ft^2) Bridge	Flow	Energy Loss (5) (ft)
353+75	Falulah Rd.	Steel-concrete	106	351.0	355.0	334	2000	1370	0.10
372+25	B&M RR	Timber pile trestle	270	357.0	361.0	339	1500	1360	0.65
388+85	Bemis Rd.	Concrete	85	374.0	374.0	361	1060	560	1.78
419+88	B&M RR	Steel girder	120	406.5	414.2	392	1580	1030	0.15
428+20	Fifth St.	Concrete	*no effect due to extreme elevation and construction*						
449+25	Sawyers Passway	Steel truss	90	420.0	425.0	410	1000	1000	0.40
451+42	B&M RR	Masonary arch	83	424.8	430.6	410	810	600+	1.44
459+75	Water St. (Rt 12)	Steel-concrete	85	433.0	432.0	413	1360	900	1.66
471+75	Laurel St. (Rt 12)	Masonry arch	135	447.8	454.0	424	2400	1200	0.60
474+00	B&M RR	Steel girder	172	432.8	439.5	425	1280	1020	0.23
475+20	Cushing St.	Steel-concrete	91	435.1	440.3	425	881	770	1.78
479+75	Commercial St.	Steel truss	80	440.5	443.1	428	980	1010	0.50
482+00	Putnam St.	Masonary arch	94	450.2	458.0	432	1140	960	0.27
483+60	B&M RR	Steel girder	112	442.6	448.8	432	1000	1000	1.20
493+60	B&M RR	Steel girder	126	449.3	457.5	438	1430	1230	0.25
505+00	Rollstone-Broad St. (3)	Steel truss	104	457.6	475.0	445	1700	910	0.11
510+10	Circle St.	Steel-concrete	75	465.5	470.5	449	1130	810	0.20
518+90	Lower River St. (Rt 31)	Steel-concrete	86	467.2	471.2	455	878	878	0.91
531+85	Footbridge	Steel truss	92	474.1	475.1	463	1000	880	0.59
539+55	Sheldon St. (4)	Steel truss/girder	70	477.1	482.0	466	880	880	1.97
552+75	Upper River St. (Rt 31)	Steel-concrete	90	486.0	489.5	475	880	1000	1.29
553+75	B&M RR	Masonary arch	85	491.2	501.2	477	1050	870	0.27
554+85	Kimball St. (Rt 12)	Steel-concrete	85	495.5	498.2	478	1250	900	1.10
562+25	Daniels St.	Steel-concrete	85	494.7	498.9	483	950	780	0.74
565+95	B&M RR	Steel girder	70	495.7	501.0	485	670	670	1.61
572+30	Oak Hill Rd	Steel-concrete	83	496.7	500.0	487	875	1050	0.97

1. Stationing is given in feet above the Leominster-Lancaster town line.
2. On all bridges the elevations of the low chord are those of the highest point of the low chord and the elevation of the top of road is given as the lowest T.O.R. point. For a steeply inclined bridge the low chord elevation may therefore exceed the T.O.R. elevation.
3. Includes both upper and lower bridges.
4. Includes the Sheldon Street bridge plus the factory upstream of the bridge.
5. Losses are based on a Q of 9,000 cfs.

TABLE I-11

PERTINENT HYDROLOGIC DATA

Location	Station	Q (cfs)	V (fps)	Friction Slope (ft/ft)	Depth (ft)
Syphon Dam (V)	36540	15,000	14.6	0.006242	14.0
		9,000	12.0	0.005978	8.9
		6,750	11.1	0.005343	9.7
Upstream of Water Street (P)	46590	15,000	11.8	0.002163	15.4
		9,000	11.3	0.003211	10.7
		5,000	10.7	0.004832	6.9
Upstream of Cushing Street (N)	47915	15,000	14.5	0.003998	12.5
		9,000	15.6	0.007616	8.8
		5,000	13.1	0.008070	6.2
Near GE Plant (M)	48680	15,000	5.2	0.000353	22.1
		9,000	6.2	0.000961	14.4
		5,000	5.7	0.001274	9.8
Vicinity of DPW Yard (K) & (L)	50458	15,000	10.2	0.001547	16.4
		9,000	8.8	0.001657	12.1
		5,000	7.7	0.002043	8.3
Circle Street (J)	50940	15,000	13.2	0.004193	12.3
		9,000	13.5	0.008012	7.6
		5,000	12.2	0.011124	4.8
River Street (I)	51860	15,000	7.8	0.001146	16.8
		9,000	10.3	0.003127	11.6
		5,000	8.4	0.003078	8.3
Nockege Street (H)	53126	15,000	11.3	0.002575	11.7
		9,000	11.8	0.004156	8.9
		5,000	10.6	0.005354	5.8
Sheldon Street (G)	53860	15,000	12.0	0.002344	12.9
		9,000	11.3	0.003568	8.3
		5,000	9.6	0.004377	5.6
Downstream of Daniel Street (D)	55900	15,000	8.4	0.002153	17.2
		9,000	9.1	0.002836	12.1
		5,000	8.0	0.002873	8.5
Downstream of Oak Hill Road (C)	57155	15,000	8.3	0.001020	19.1
		9,000	8.8	0.002016	12.6
		5,000	8.0	0.002759	8.0
Cowees Mill Dam (A) & (B)	57700	15,000	10.4	0.001962	19.2
		9,000	10.0	0.002768	15.7
		5,000	8.7	0.003211	8.6

14. FREEBOARD

Freeboard is the difference in elevation between the computed design water surface elevation and the top of a protective wall or dike. It is the amount of added height in protection provided as a safety factor against inaccurracies in profile computations and other unknowns.

The rehabilitation of the Fitchburg channel will restore only that amount of freeboard that existed in the original project and no special provisions are proposed for added freeboard. The resulting freeboard will vary from near zero at localized areas to about 4 to 5 feet with the average being about 3 feet. The amount of freeboard is illustrated on Plate I-6, by the distance between the water surface profile and the minimum top of bank. The numerous structures and channel transitions in Fitchburg create many unknowns that could effect the computed water surface. The possible presence of debris or ice jams during a flood are also another indeterminate in computing the design water surface. However, freeboard was not considered vital since the river channel is mostly below normal grade and some shallow short duration overtopping of the riverbank would not pose a serious threat to human life or property and would not mean the breeching of the protective system such as in the case of high earth dikes. Also, it is noted that these areas having minimal freeboard are generally localized "pockets" in the overbank areas where any overtopping would result in flooding of a limited area.

15. RIPRAP DESIGN

The design of riprap protection was based on the "tractive force" theory as originally set forth in the draft report entitled, "Criteria for Graded Stone Riprap Channel Protection", dated 20 April 1966, and as modified in subsequent guidelines such as EM 1110-2-1601.

The basic tractive force method utilizes DuBoy's Law for average boundary shear:

$\overline{To} = \gamma RS$

$\overline{To}$ = average boundary shear

γ = unit weight of water

R = hydraulic radius

S = energy gradient or friction slope

The ability of stone riprap to resist movement by tractive force is then related to the equivalent diameter of the 50 percent by weight finer stones designated "D_{50} minimum". Based on the above referenced criteria the following relationship can be derived between depth of flow, friction slope and permissible D_{50} minimum.

$$D_{50} = 15.2\ YS\ \left(1 - \frac{\sin^2\phi}{\sin^2\theta}\right)^{-0.5} \cos\phi$$

Y = Depth of flow

S = Slope of energy gradient or friction slope

ϕ = Channel side-slope

θ = Angle of repose of riprap = 40^o

Note: Formula based on unit weight of water = 62.4 lbs/ft^3 and of stone = 165 lbs/ft^3

Both velocities and tractive forces are highly regulated in the North Nashua River through Fitchburg due to the backwater effect and throttling nature of the numerous bridge crossings and restrictive river sections. Therefore, to allow for numerous unknowns and safety in design, riprap was sized based on the average slope(s) of the river through the reach, which is 0.8 percent, and the average depth (y), which is 10 feet. This resulted in one class of riprap, having a D_{50} minimum of 1.5 feet, being generally specified for all replacement or supplemental work with the following exceptions due to varied local conditions:

a. On the downstream apron of the Fitchburg Gas and Electric Company dam.

b. On the downstream apron of the Bemis Road dam.

The computed velocities at these two locations were 13.0 and 11.5 feet per second, respectively.

For these two locations it was considered more appropriate to relate the stone size directly to the velocity of the water as set forth in "Hydraulic Design Criteria", sheet 712-1, Stone Stability Velocity versus Stone Dimeter, as revised in September 1970.

The velocity required by flowing water to move a stone of a given diameter by sliding it along the streambed or by overturning it has been shown by Isbash to be:

$$V = C\left[2g\left(\frac{\gamma_s - \gamma_w}{\gamma_w}\right)\right]^{\frac{1}{2}} (D)^{\frac{1}{2}}$$

V = Velocity in fps

C = a coefficient

G = acceleration of gravity, ft/sec^2

γ_s = Specific weight of stone, lb/ft^3

γ_w = Specific weight of water, lb/ft^3

D = Stone diameter, ft

Experimentation has resulted in coefficients of 0.86 when movement by sliding resulted and of 1.20 when overturning caused the movement. Extensive testing at the U.S. Army Engineer Waterways Experiment Station Laboratory for the design of riprap below stilling basins indicates that the coefficient of 0.86 should be used with the average flow velocity over the end sill for sizing riprap because of the high turbulence level in the flow. For areas of low flow turbulence such as river closures, the coefficient of 1.20 may be used.

Relating the stability of the riprap to the D_{50} minimum size the following relationship may be derived:

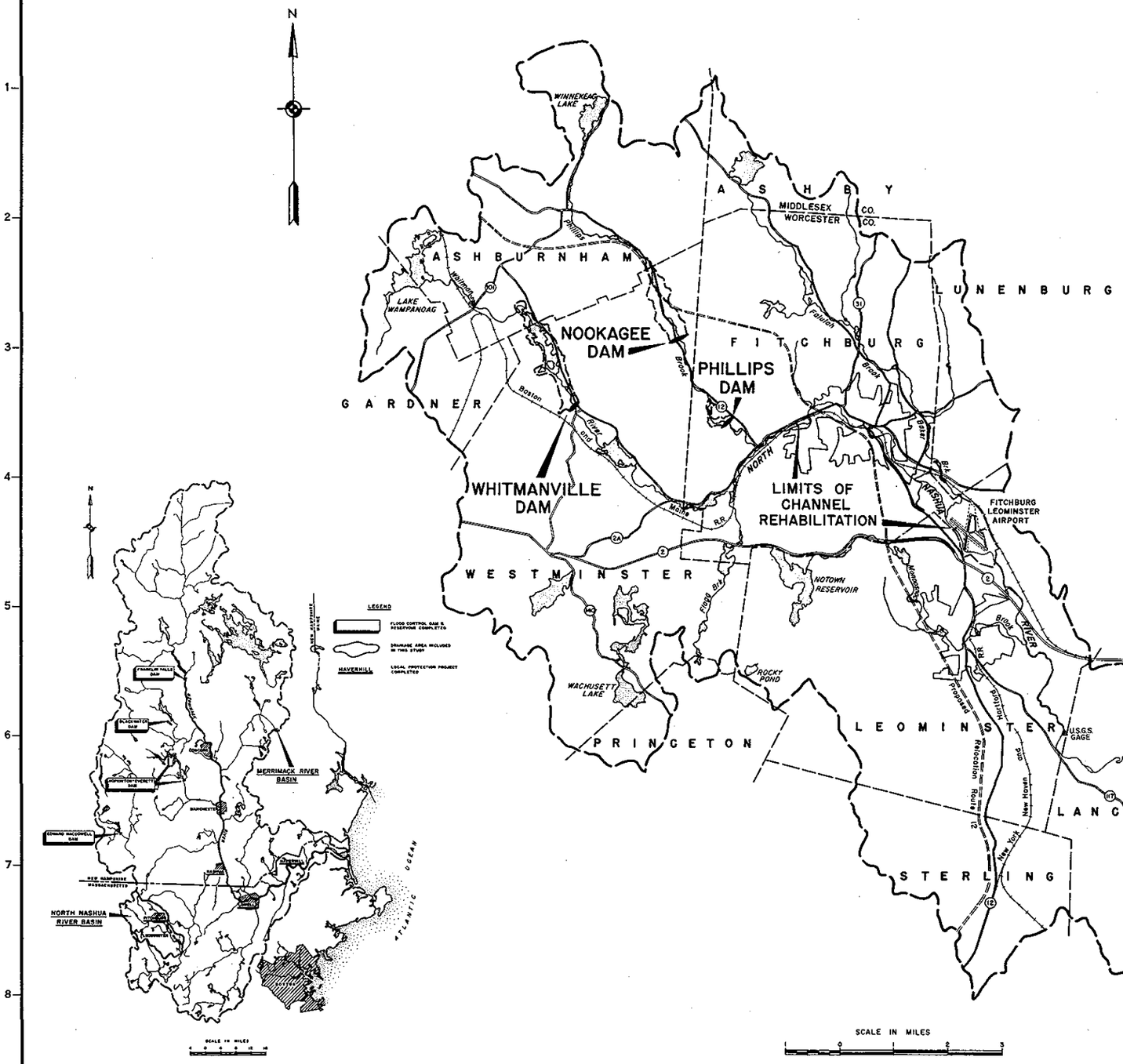
$$D_{50} = (9.45 \times 10^{-3} V^2)/C^2$$

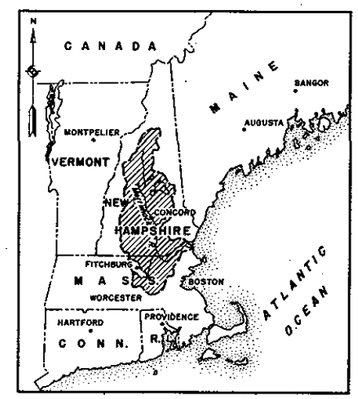
Note: The equation is based on a unit weight for stone of 165 lb/ft^3 and for water of 62.4 lb/ft^3.

Based on the above, the D_{50} minimum size for riprap at the Fitchburg Gas and Electric Company dam and at the Bemis Road dam, are 2.2 and 1.7 feet, respectively. The coefficient(c) used in the formula for these two locations, based on the criteria set forth above, was 0.86.

CORPS OF ENGINEERS

U. S. ARMY





LOCATION MAP

SCALE IN MILES 25 0 25 50 75 100

SCALE IN MILES 0 1 2 3

LEGEND

DAM AND RESERVOIR AREA

NOTE: Present EO plan combines Nookagee and Phillips Reservoirs into one larger Phillips Reservoir.

Channel Rehabilitation is a Separable Component of Comprehensive Flood Control Plan.

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

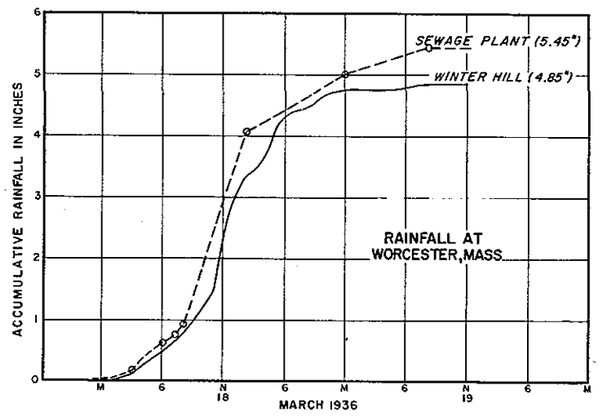
DES. BY W.J.W.	DR. BY M.S.	CK. BY
SUBMITTED:		
CHIEF, SECTION		
APPROVAL RECOMMENDED:		
CHIEF, ENGR. DIV. BRANCH		
REVIEWED:		
PROJECT ENGINEER		
APPROVAL RECOMMENDED:		
CHIEF, BRANCH		

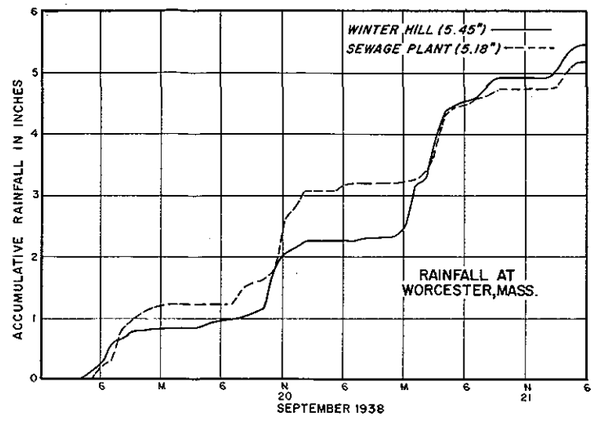
WATER RESOURCES DEVELOPMENT PLAN
MERRIMACK RIVER BASIN
NORTH NASHUA RIVER
FLOOD CONTROL
BASIN MAP
FITCHBURG MASSACHUSETTS

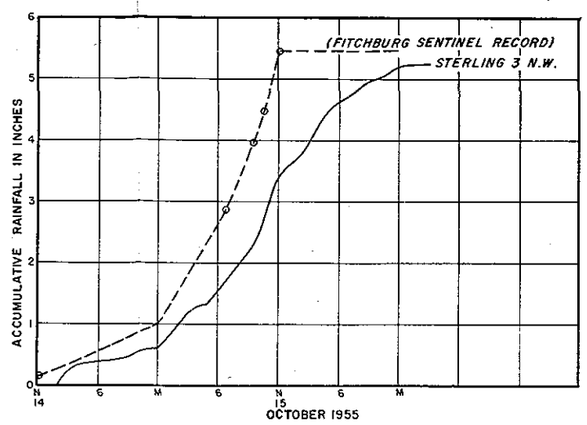
APPROVED DATE
CHIEF, ENGINEERING DIVISION

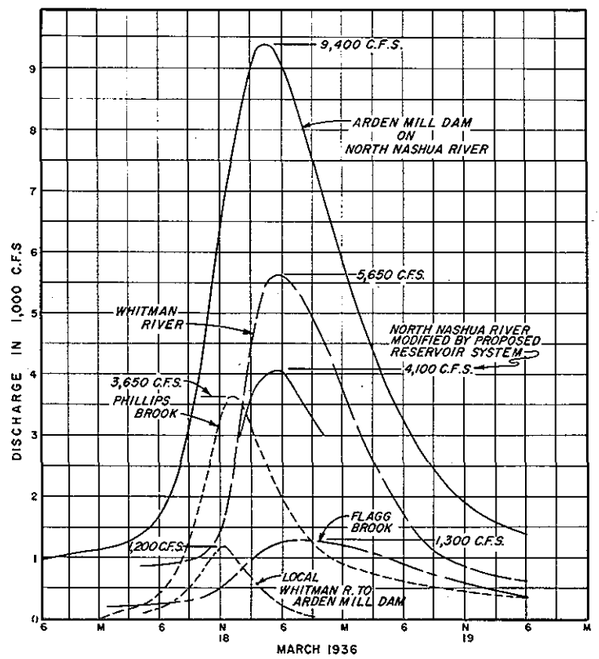
SCALE AS SHOWN | SPEC. NO.
DRAWING NUMBER

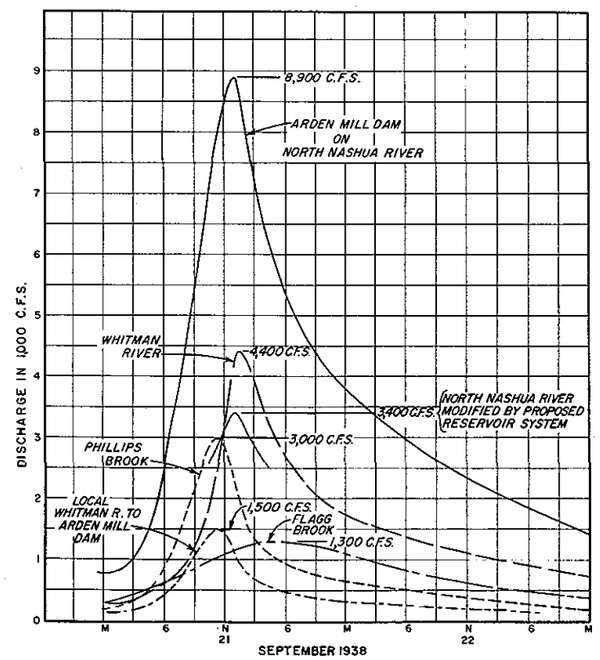
PLATE I-1

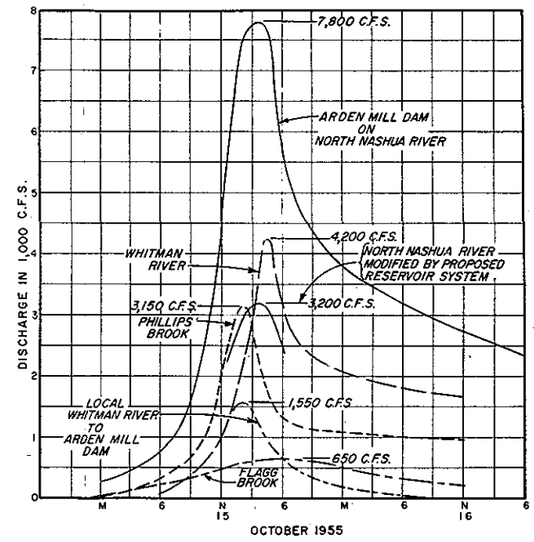












PROPOSED RESERVOIR SYSTEM

RESERVOIR	DRAINAGE AREA
1.) WHITMANVILLE	17.5 SQ. MI.
2.) NOOKAGEE *	11.0 SQ. MI.
3.) PHILLIPS *	(NET) 5.0 SQ MI.

* NOTE: Present EQ plan combines Nookagee and Phillips Reservoirs into one larger Phillips Reservoir.

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY R.W.M. | DR. BY G.H.D. | CK. BY E.P.S.

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CHIEF, SECTION
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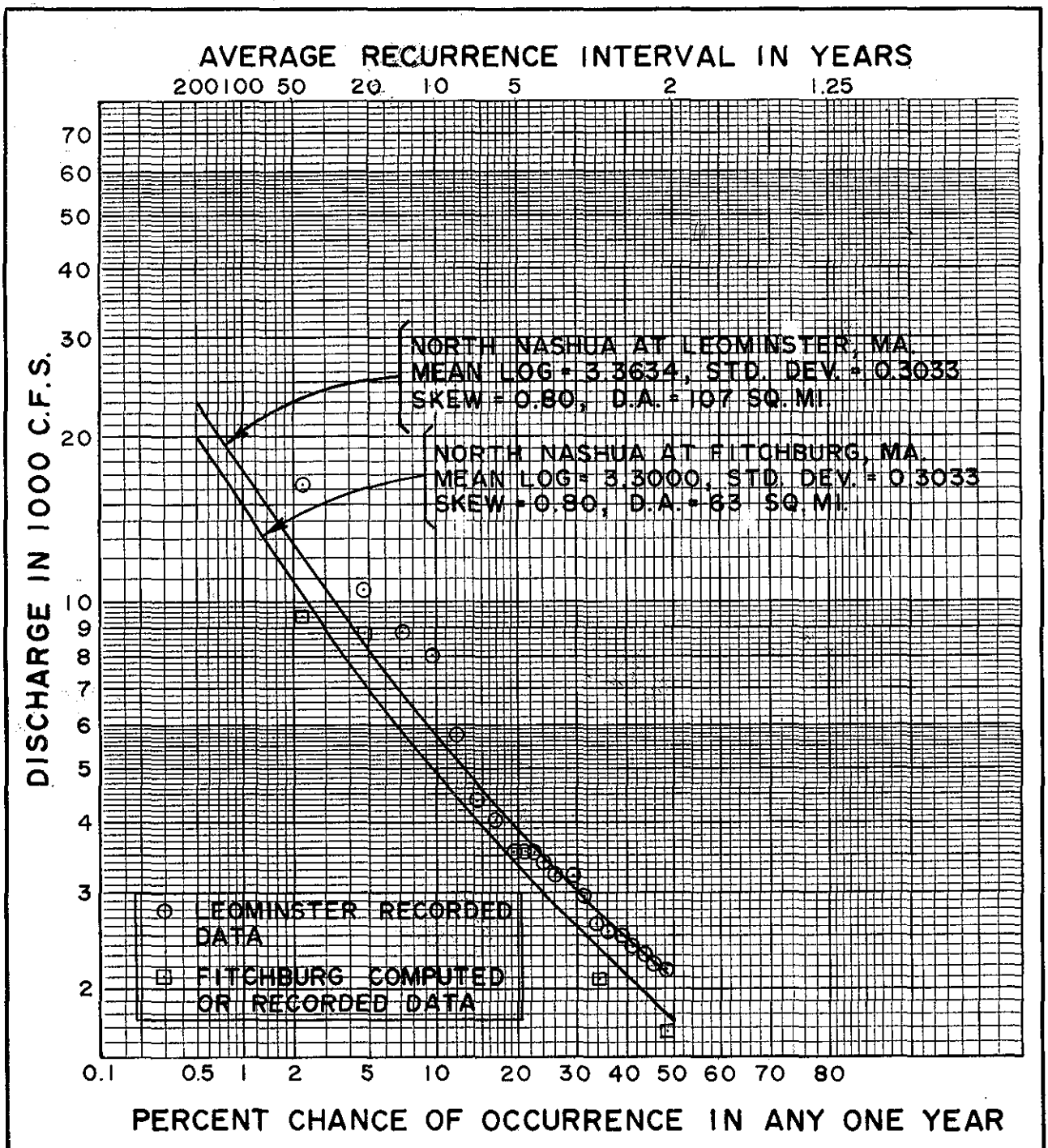
APPROVAL RECOMMENDED:
CHIEF, BRANCH

WATER RESOURCES DEVELOPMENT PLAN
MERRIMACK RIVER BASIN
NORTH NASHUA RIVER FLOOD CONTROL
FLOODS OF RECORD AT FITCHBURG
FITCHBURG MASSACHUSETTS

APPROVED DATE
CHIEF ENGINEERING DIV.

SCALE AS SHOWN | SPEC. NO.
DRAWING NUMBER
SHEET

PLATE I - 2



WATER RESOURCES DEVELOPMENT PLAN

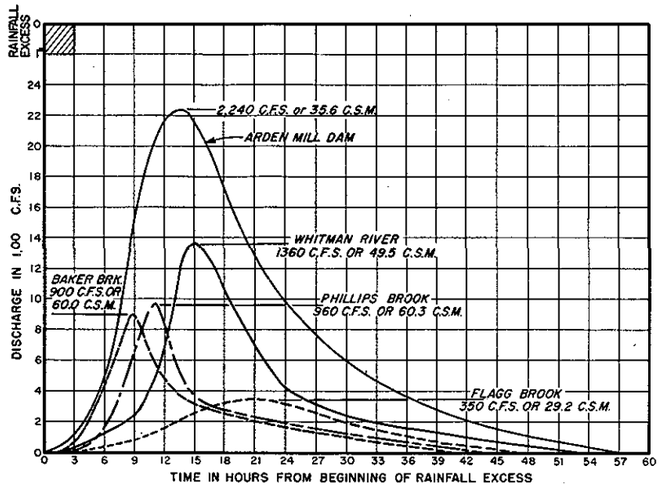
MERRIMACK RIVER BASIN

NORTH NASHUA RIVER WATERSHED

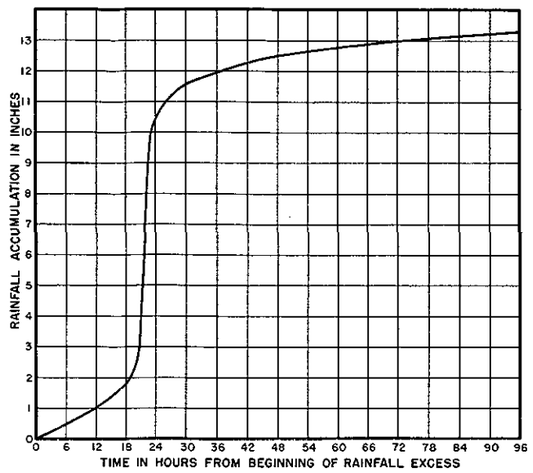
PEAK DISCHARGE FREQUENCY CURVES

NEW ENGLAND DIVISION, WALTHAM, MASS.

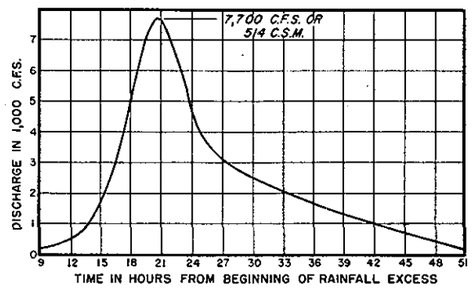
PLATE I-3



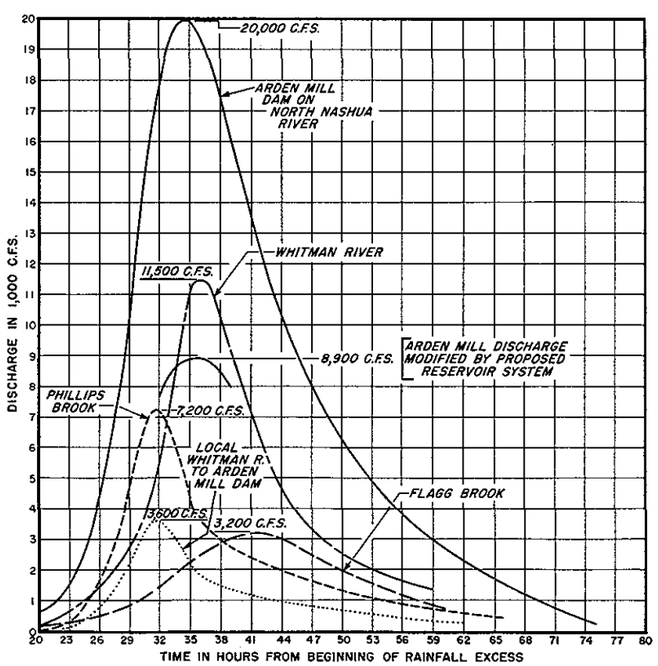
THREE- HOUR UNIT HYDROGRAPHS



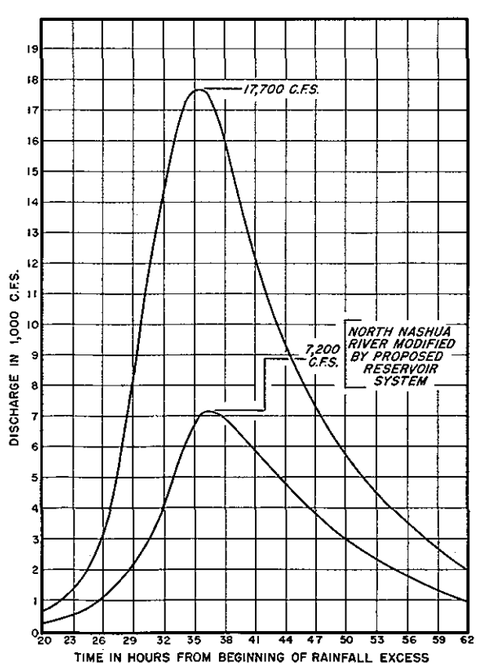
STANDARD PROJECT STORM RAINFALL



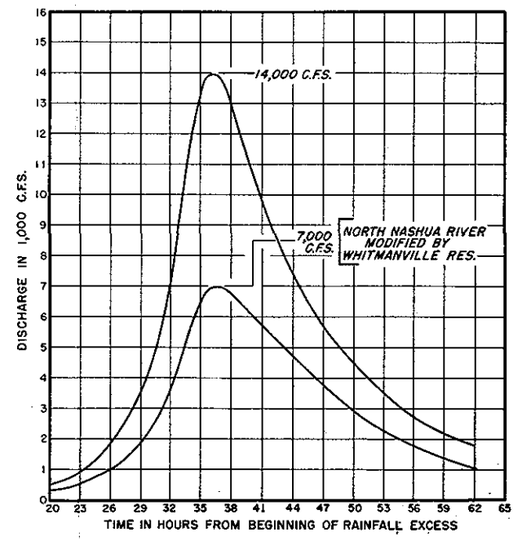
BAKER BROOK AT SUMMER STREET



NORTH NASHUA RIVER
AT ARDEN MILL DAM



NORTH NASHUA RIVER
BELOW MOUTH OF PHILLIPS BROOK



NORTH NASHUA RIVER
ABOVE MOUTH OF PHILLIPS- BROOK

PROPOSED RESERVOIR SYSTEM

RESERVOIR	DRAINAGE AREA
1.) WHITMANVILLE	17.5 SQ. MI.
2.) NOOKAGEE *	11.0 SQ.MI.
3.) PHILLIPS *	(NET)5.0 SQ.MI.

* NOTE: Present EQ plan combines Nookagee and Phillips Reservoirs into one larger Phillips Reservoir.

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY R.W.M.	DR. BY M.S.	CK. BY R.W.M.

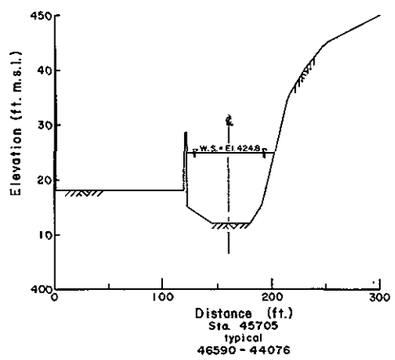
SUBMITTED: CHIEF, SECTION
APPROVAL RECOMMENDED: CHIEF, TECH. ENG. BRANCH
REVIEWED: PROJECT ENGINEER
APPROVAL RECOMMENDED: CHIEF BRANCH
APPROVED: CHIEF ENGINEERING DIV. DATE

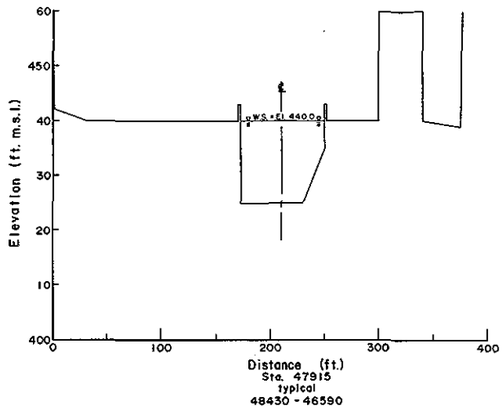
WATER RESOURCES DEVELOPMENT PLAN
MERRIMACK RIVER BASIN
NORTH NASHUA RIVER
FLOOD CONTROL
STANDARD PROJECT FLOOD AT
FITCHBURG
FITCHBURG MASSACHUSETTS

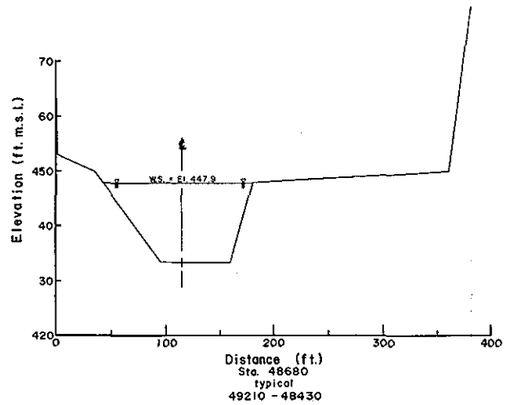
SCALE AS SHOWN | SPEC. NO.
DRAWING NUMBER
SHEET

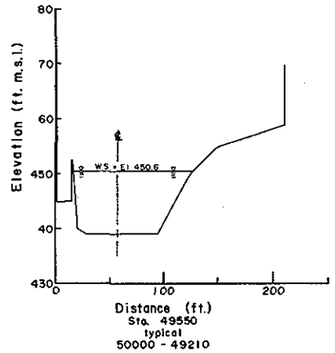
PLATE I-4

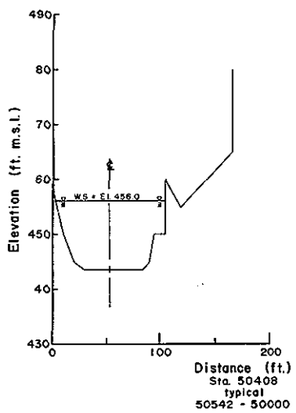
CORPS OF ENGINEERS

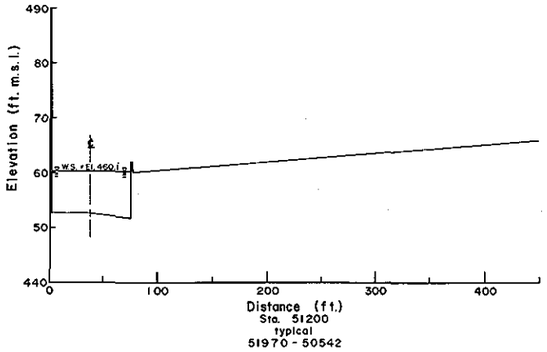


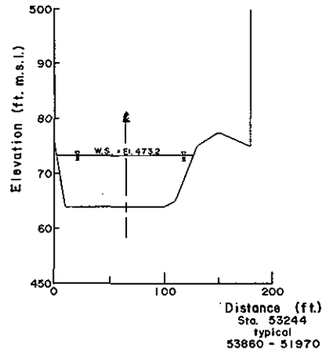


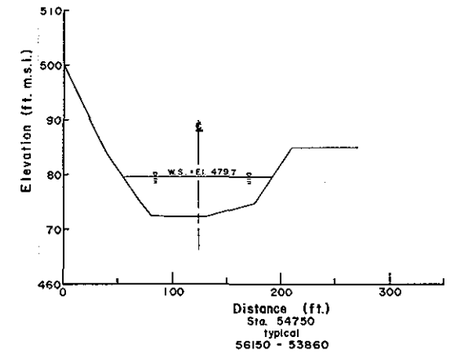


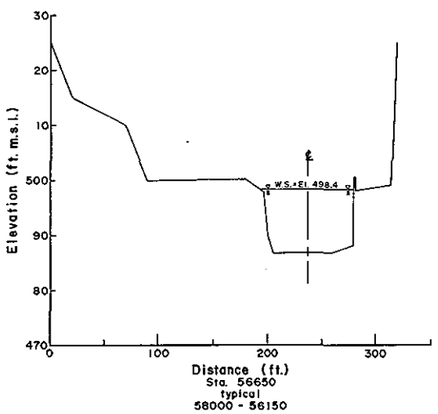


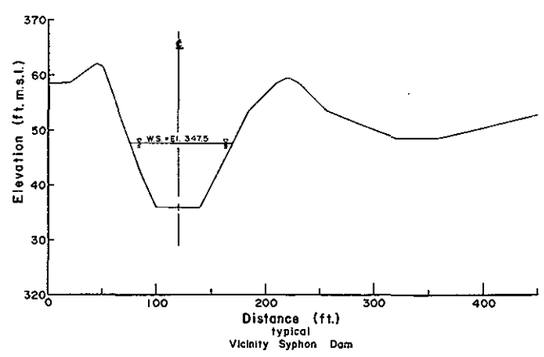












NOTES:

Water surface elevations are given for the design flow of 9000 c.f.s. and reflect completion of all scheduled rehabilitation work. The given elevation is applicable to the cross-section station indicated only, and will vary throughout a given reach.

Syphon Dam section is a straight line interpolation between the cross-sections upstream and downstream from the dam.

All other cross-sections are taken from imput data utilized in the HEC-2 Water Surface Profile Computer Program.

SAFETY PAYS

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

SUBMITTED:
CHIEF, SECTION
APPROVAL RECOMMENDED:
CHIEF, TECH. ENG. BRANCH
REVISED:
PROJECT ENGINEER
APPROVAL RECOMMENDED:
CHIEF, BRANCH

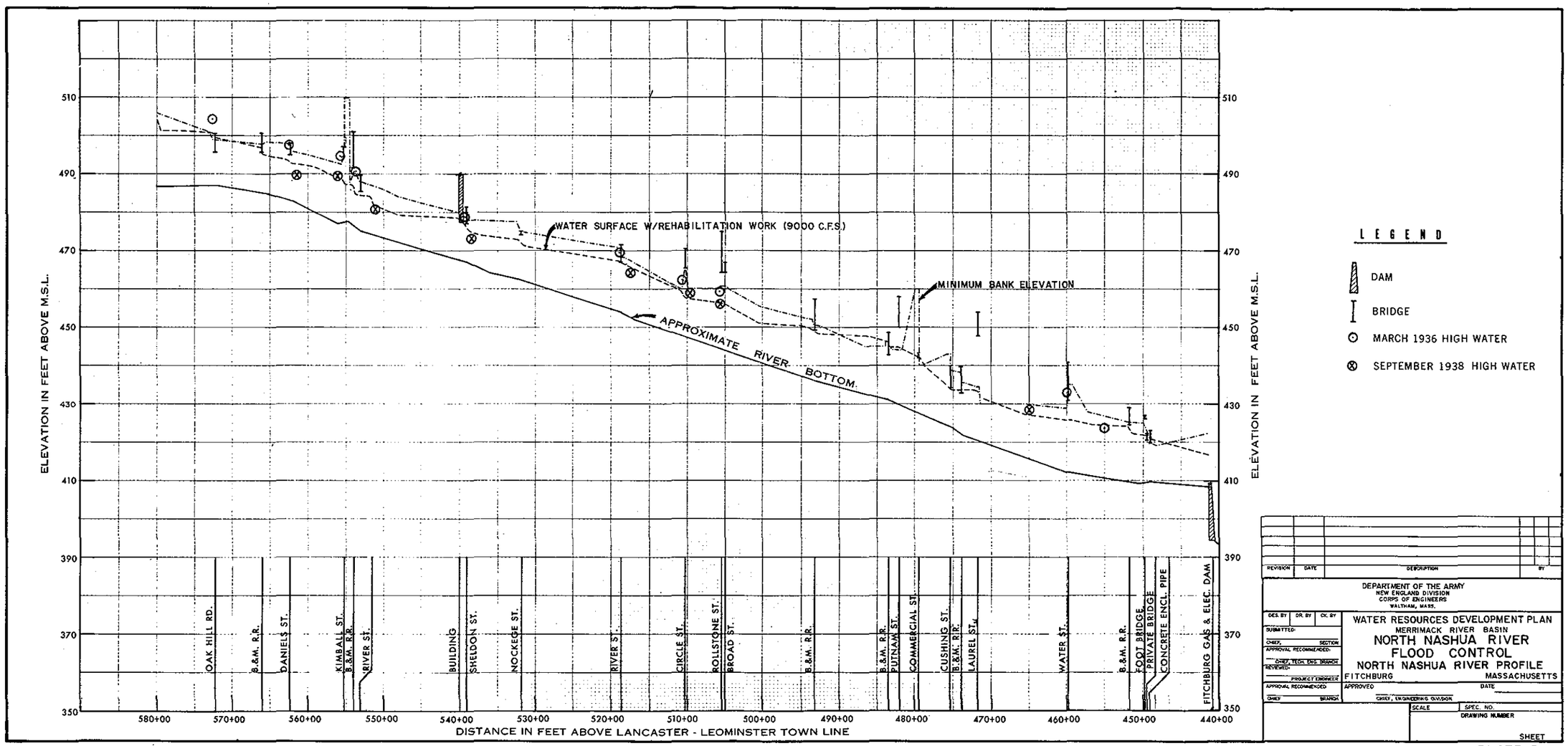
WATER RESOURCES DEVELOPMENT PLAN
MERRIMACK RIVER BASIN
NORTH NASHUA RIVER WATERSHED
TYPICAL CROSS SECTIONS

APPROVED
DATE
CHIEF, ENGINEERING DIVISION

SCALE | SPEC. NO.
DRAWING NUMBER
SHEET

PLATE I-5

U. S. ARMY



REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY	DR. BY	CK. BY

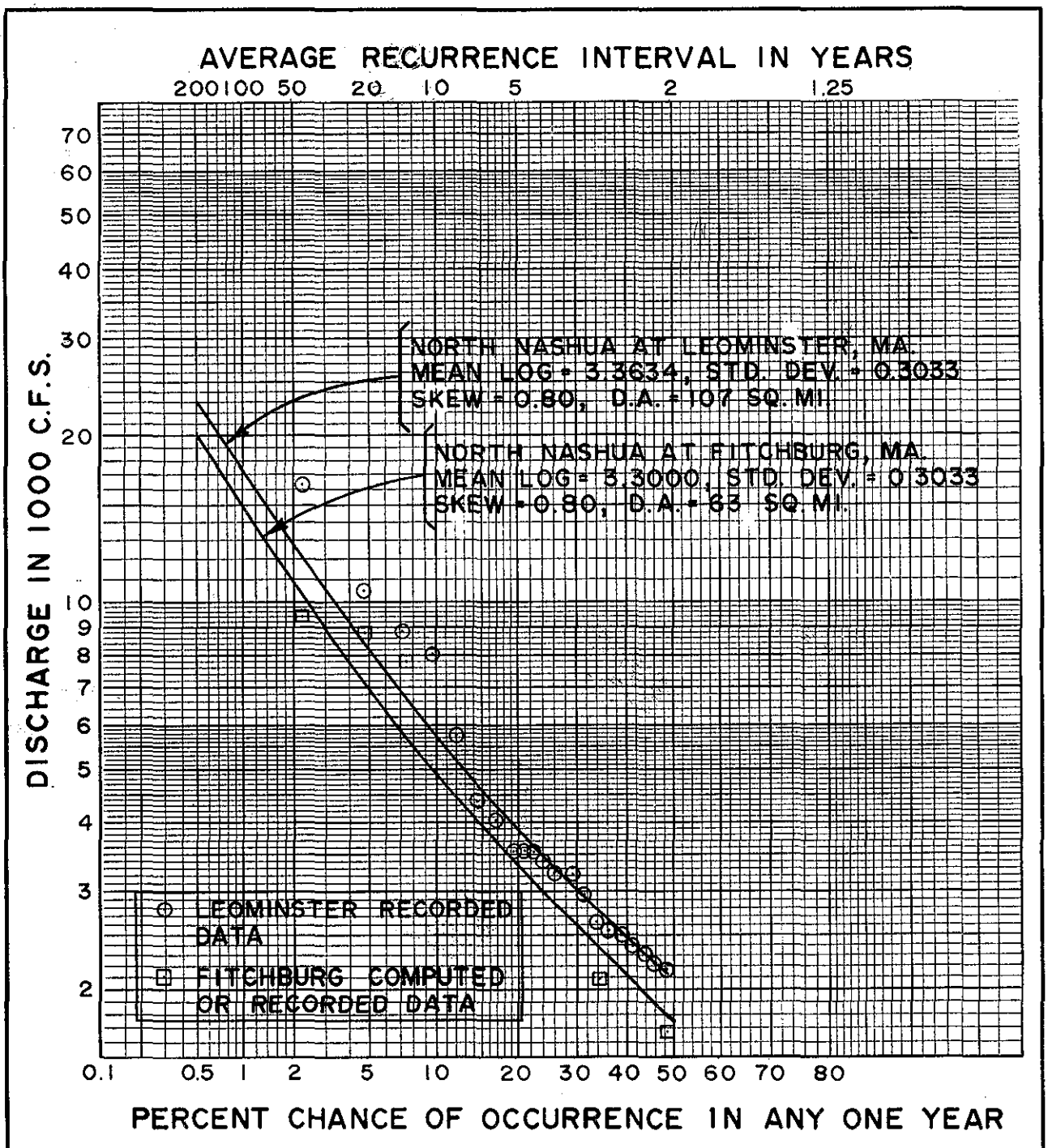
SUBMITTED:
CHIEF, SECTION
APPROVAL RECOMMENDED:
CHIEF, TECH. ENG. BRANCH
REVIEWED:
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF BRANCH

WATER RESOURCES DEVELOPMENT PLAN
MERRIMACK RIVER BASIN
NORTH NASHUA RIVER
FLOOD CONTROL
NORTH NASHUA RIVER PROFILE
FITCHBURG MASSACHUSETTS

APPROVED DATE
CHIEF, ENGINEERING DIVISION

SCALE | SPEC. NO.
DRAWING NUMBER
SHEET

PLATE I-6



WATER RESOURCES DEVELOPMENT PLAN
MERRIMACK RIVER BASIN

NORTH NASHUA RIVER WATERSHED

PEAK DISCHARGE FREQUENCY CURVES

NEW ENGLAND DIVISION, WALTHAM, MASS.

PLATE I-3

APPENDIX II

ENVIRONMENTAL ASSESSMENT

ENVIRONMENTAL ASSESSMENT

NORTH NASHUA RIVER CHANNEL IMPROVEMENT

FITCHBURG LOCAL PROTECTION

FITCHBURG, MASSACHUSETTS

Prepared by

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS 02154

NOVEMBER 1977

APPENDIX II

APPENDIX II
ENVIRONMENTAL ASSESSMENT

TABLE OF CONTENTS

1.00 PROJECT DESCRIPTION

This project proposes the rehabilitation of the North Nashua River Local Protection Project. It consists of repair and/or reconstruction of those walls, cribs, and grouted riprap which have deteriorated. In addition, there will be removal of channel obstructions and depositions and reshaping and scraping the bottom so as to provide a relative smooth channel with relative uniform width at various places in the channel, large isolated stones will be placed randomly for environmental enhancement.

Because of high channel velocities during flood periods, banks are required to be protected against erosion, and consequent deposition in the improved channel. Within the past 40 years, there has been some major flooding in the North Nashua River Basin. Four substantial floods have occurred between the years 1936 - 1955. In 1937, work was done under a Work Relief Project to improve conditions in the river and provide a means of flood control. It consisted mainly of installation of cribs and walls, and also placement of grouted riprap. Since then only emergency repair work has been done, once in 1955, and again in 1968. This work consisted of removal of gravel deposits and debris, and filling washed-out riverbanks. Concrete cribbing was also stabilized.

Over the years, these works have deteriorated so extensively that they no longer fulfill their design function. The cribbing is broken, or covered by stone or plant growth. Concrete slabs have fallen into the river, adding to the already existing debris. The bottom of the river is covered mostly by sludge from the paper mills, with the water carrying paper fibers, creating stagnant pools of the sludge.

The intent of the project is to restore the deteriorated channel to its 1937 condition and capacity of 9,000 cubic feet per second. It is expected that the rehabilitation work will improve the visual aspects of the channel and riverbanks, while also providing a harmonious relationship with the stream environment and its functional purpose of flood control.

The existing project area begins upstream in the city of Fitchburg at the site of the now removed Cowee's Mill Dam, and extends 5.5 miles downstream to the Leominster town line below the Fitchburg Airport. The immediate area of interest extends from Cowee's Mill Dam 4 miles downstream to the vicinity upstream of the Falulah Road Bridge. An abridged scope of the work is shown on Attachment No. 1.

2.00 ENVIRONMENTAL SETTING WITHOUT THE PROJECT

The North Nashua River Basin is situated in north-central Massachusetts in the northern portion of Worcester County and north-west Middlesex County. The study area, located in Fitchburg, is one of the 10 Standard Metropolitan Statistical Areas (SMSA) in Massachusetts and constitutes the major population center within the basin. The river, above the confluence of Baker Brook, controls some 64 square miles of watershed drainage.

The North Nashua River is formed at the confluence of the Whitman River with Flagg Brook in the city of Fitchburg, Worcester County, Massachusetts at an elevation of 590 feet above mean sea level. The principal tributaries are Whitman River, Flagg, Phillips, Baker and Monoosnoc Brooks, with a number of smaller streams adding to the system.

The river flows in a substantially west to east direction through a typically urban industrially and commercially oriented portion of the city. The surrounding topography is characterized by wide valleys and broad, steep sided hills, affording a watershed which is highly conducive to rapid run-off.

The existing protective works at Fitchburg were constructed following the major flood of 1936. At several places earth banks were protected with concrete crib walls, at other locations

the riverbed and toes of the banks were protected against scour by grouted riprap. The work included channel enlargement, relocation of the outlet of Punch Brook, and removal of several abandoned dams.

Upon examination of the existing project, it was found that its present condition has vastly deteriorated. Cultural debris in the river includes discarded shopping carts, trash, and paper fibers; there is also a large amount of rock debris. Large stone slabs which were either remains of old structures, or of unknown origin have tumbled into the stream along the bank.

At a number of sites, observations included deteriorated concrete cribbing, some with dumped granite in front of it. The banks at River Street Bridge, Circle Street Bridge, and Walnut Street were among those which were in the worst condition.

At certain areas around the banks a large amount of repair was needed. They have either eroded to the point of needed repair, or had rock landslides.

The basin is a center of industrial and commercial areas critical to the economy of central Massachusetts. Manufacturing is the principal occupation, and employment by industries within the floodplain of the river represents over 50% of the total employment in Fitchburg. The serious consequences of any additional flooding of past magnitudes would gravely retard the current progress of economic and social well being.

The over-polluted state of the North Nashua has gradually been improved over the past couple of years due to the construction and operation of two wastewater treatment plants, but pollution is still a major factor in the present state of the river. The stream flow is moderately rapid because of the moderately steep gradient of the streambed. The primary cause of the pollution is the discharge of industrial wastes, principally paper wastes, along the upper and middle portions of the river. As a result of these discharges, a minimum amount of the natural environment remains. The fauna of the area has been greatly reduced over the years, with the flora being indicative of a disturbed and polluted area. The project area is typical of any such area where uncontrolled commercial and industrial development has eliminated the original natural environment.

The North Nashua River, due to its polluted state, is not used for any recreational purposes. the water is multicolored, turbid, at times releasing an offensive odor.

3.00 THE ENVIRONMENTAL IMPACT OF THE PROPOSED ACTION

Major actions that will be undertaken are:

(1) Bank Restabilization

(2) Rock and Debris Removal

(3) Granite, Concrete and Gabion Wall Construction

(4) Concrete Cribbing and Grouted Riprap Repair

(5) Streambank Vegetation Removal

(1) Bank Restabilization

There will be bank restabilization at the site of the now removed Cowee's Mill Dam, and also in the vicinity of the Falulah Street Bridge. This work will consist of placing large stones, slabs and dumped rock upon the sides of the banks.

Work will also include the removal of debris which has collected at the foot of the banks.

No adverse effects on the environment can be foreseen.

(2) Rock and Debris Removal

Removal of rock and debris will vastly improve the appearance of the river. In some places the flow of the river will be restored by the reshaping and scraping of the river bottom, thereby helping to wash downstream waste material which has collected. Due to pollution, the aquatic species have been eliminated, and those adverse effects on them which might normally be associated with this action are inconsequential.

(3) Granite, Concrete and Gabion Wall Construction

Wall construction work will be undertaken at the following sites which can be located on the various plates,

Concrete - Locations F, O, P and Q

Granite - Location B

Gabion - Location A

The impacts as a result of this construction will be minimal. In cases where it necessitates the removal of vegetation, revegetation measures will be implemented,

(4) Concrete Cribbing and Grouted Riprap Repair

This repair work will have little adverse effect on the surrounding environment. Upstream of Oak Hill Road some Japanese bamboo is abundant in front of the walls which require repair. Although this will be removed, it is a minor effect, as natural revegetation will most likely occur.

(5) Streambank Vegetation Removal

Removal of existing large trees will be implemented in those areas where they may interfere with flood flows. Revegetation measures will be taken at most locations where the existing vegetation is removed, being carried out at those places where stream flow will not be impeded or act as a catchment for floating debris which would increase flooding. Therefore, any vegetation removal will have a minor impact as there will be controlled natural revegetaion or landscaping.

4.00 ANY ADVERSE ENVIRONMENTAL EFFECTS WHICH CANNOT BE AVOIDED SHOULD THE PROPOSAL BE IMPLEMENTED

There are no adverse environmental effects of any significance associated with this project. No conservation groups or other interests are known to oppose the proposed rehabilitation, although certain groups have expressed an interest in the development of recreational opportunities in the area.

5.00 ALTERNATIVES

The local protection works in the city of Fitchburg were only one of the many projects deemed necessary to alleviate the total flooding problem. All practicable means of solving the flood control problem study area were considered. Inasmuch as the project is a rehabilitation of existing local flood protection facilities no other structural alternatives were considered.

The possibility of nonstructural measures was investigated and an analysis of nonstructural types of alternatives is as follows:

Alternative No.	Plan	Comment
1	No Action	The "no action" plan would be to leave the existing project in its present condition of disrepair and with physical obstructions to river flow. There would not be any monetary costs involved, however, and such a course of action would be unsuitable and not be an aid in reducing flood problems.
2	Evacuation of Floodplain	The removal of all existing development in the floodplains of the Fitchburg area would cause tremendous disruption of human needs and resources. It would cause adverse social and institutional effects associated with large scale relocation and the cost, although not estimated, would be exorbitant. Such a plan would eliminate the need for channel improvements.
3	Floodplain Management	This plan would greatly reduce further encroachment on floodplain areas, however, it does not protect the highly developed areas of Fitchburg against floods. The floodplain in the city is predominantly commercial and industrial with large content values. (i.e., raw materials, equipment and manufactured goods).

4	Floodproofing and Evacuation	This alternative provides individual type flood protection for some properties and areas, However, areas and bridges, roads, etc., between the protected buildings would remain subject to flooding, siltation and debris deposition. It does have potential application for some individual properties but not for flooded areas as a whole.
5	Removal of all existing works	The possibility of removing all the existing works and starting all over would be impractical. Also it would not significantly increase protection over that provided by the proposed project.
6	Channel Rehabilitation	This alternative involves the accomplishment of physical improvements to an existing accepted project. There will be minimum environmental, social-economic impacts and disruption to existing private and public facilities, enterprises, etc. The Improvement Costs are not excessive and the Benefit-Cost Ratio of the project is favorable and above unity and will provide a reduction in losses from flooding.

Due to the congested built-up area of the city floodplain which mainly comprises a commercial and industrial development, it is considered that the possible nonstructural alternatives are not totally feasible, acceptable or suitable.

The channel rehabilitation project is considered the most acceptable alternative from the points stated above. The channel rehabilitation project has been the authorized project since 1966 and is the "selected" plan of prior studies and consideration of other type alternatives. An updated review of the project has been made and it is considered that the channel rehabilitation remains sound and should be accomplished.

6.00 THE RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES OF MAN'S ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

The "long-term productivity" of the natural environment in this project area is no longer subject to consideration because it has long since been destroyed. Present conditions are the result of local short-term use. The project will enhance the appearance of the area, and result in an orderliness not now present.

7.00 IDENTIFICATION OF "ANY IRREVERSIBLE OR IRRETRIEVABLE COMMITMENT OF RESOURCES WHICH WOULD BE INVOLVED IN THE PROPOSED ACTION SHOULD IT BE IMPLEMENTED"

There will be no irreversible or irretrievable commitment of resources which would be involved in the proposed local protection project should it be implemented, other than the labor and material required to construct the project.

8.00 ENVIRONMENTAL FACTORS

The factors listed have been observed and reviewed as to the kinds of effects they will have in the construction area.

The various environmental impacts associated with this project have been categorized under the following principal headings: Aesthetics, Fisheries, Wildlife Habitat, Plant Life, Social, Noise and Historical.

Because each area of the river looked at was in poor condition, the environmental factors listed will have a minimal impact.

a. Aesthetic. The appearance of the local protection project will be improved by completion of the project. Improvement will result from the removal of debris, repair of deteriorated works and aesthetic enhancement measures such as texturing of concrete walls and replanting of riverbanks.

b. Fisheries. The survey did not reveal any forms of fish life; therefore, there will be no impact on fisheries. All species have long since been destroyed.

c. Wildlife Habitat. The area is not a significant wildlife habitat; therefore, there will be no impact.

d. Plant Life. Certain shrubs and trees which may interfere with floodwater flow will be removed during construction. Measures will be taken to mitigate vegetation losses when possible by replanting selected shrubs and small trees at higher elevations above the riverbed.

e. Recreation. At present the river is not used for any recreational purposes, and the commercial usage will not be effected. This flood control project will help to insure social and economic well-being. The new rehabilitation work will improve the visual aspects of the channel and the riverbanks. All work is being coordinated with the city of Fitchburg to assist in their plans for future recreational development along the river.

f. Noise. Noise will increase, but only during construction.

9.00 ECONOMIC AND SOCIAL IMPACTS

Planning for flood control requires an understanding of the many diverse forces interacting in the proposed impact (study) area. Moving towards economic growth, housing and industrial development, protection of valuable natural resources, higher or lower taxation, changes in transportation patterns, etc. will affect the quality of life in any particular region. Complex interacting social, economic, and environmental factors may bring about both adverse and beneficial effects to the same community.

Having as much information, and raising as many questions and issues as possible is essential in order to better examine different alternatives and arrive at those plans which meet most consensus and which amy be most practical and desireable. Such plans would capitalize on beneficial effects while minimizing or mitigating possible adverse effects in both the short and long run.

Fitchburg has a well balanced economic base and accounts for one-half of the firms in the SMSA, 55% of the annual payroll, and 53% of the average annual employment. Manufacturing with 52% of the total employed population accounts for the largest source of employment. The three leading firms, measured in

employment, in order of importance were fabricated metals, paper products, and machinery industries (except electrical). Within the watershed area and principally in Fitchburg, paper production amounts to 20% of the total in Massachusetts. In the past ten years, the population in Fitchburg has remained relatively stable; yet the SMSA's population has increased by 8%. Thus the city of Fitchburg is the employment center for the population of approximately 100,000, residing in the SMSA.

In the past, employment has been hampered by the attraction of many of the region's industries to other parts of the nation. High wages, ever increasing tax burdens, and the high cost of energy and transportation have led to the exodus of manufacturing firms from both the region and state. The unemployment rate during 1976 was 10-1/2% for the SMSA. This was 3% higher than the national average. Therefore, anything that can contribute to the development of employment opportunities in the region should be welcomed.

The positive contribution of the project is the prevention of flood losses. Physical losses include only such losses or damage to structures, machinery and stock, and cost of clean-up and repairs. Non-physical losses include loss of unrecoverable wages and business cost of temporary facilities, and increased cost of operation.

Other positive effects can be associated with the proposed or examined projects. These could include: avoidance of road washouts thus aiding the motorists and travelers, possible additional recreation, reduction of the probability of injury or death attributed to flooding, the easing of the fear of flooding, the reduction of the possibility of flood waters disrupting water supply and sewage collection systems which may cause contamination and spread of disease, the availability of jobs and employment opportunity during construction of projects and help in the maintenance of employment.

Such flood protection would result in economic and social enhancement of Fitchburg in particular and the water shed region in general, in the long run. The reduction of damages from floods would yield great economic benefits, especially to industry and may halt the flight of manufacturing jobs. It may reduce the abnormally high level of unemployment and at the same time encourage industrial growth. The serious consequences of any additional flooding of past magnitudes would gravely retard the current progress of economic improvement and social well being.

All of the project plans would cause some local air and noise impacts because of clearing, grading, and filling operations during the 1½ year construction period. All local streets would experience increased traffic from trucks bringing in materials

for construction and removing debris. Such truck traffic would bring corresponding air quality, noise, safety, and congestion impacts. Most effects during any project construction tend to be temporary, rather intense and the impact more limited to the specific site location. These impacts are of a temporary nature and should cause only minor inconvience. Impacts after project implementation may be according to plans as well as unforseen. Some will be site specific; other will go beyond the locality.

The non-action alternative shifts the major responsibility and burden of flood protection to those who live and work on the flood plain. Under the no action (do nothing) alternative, no new regional or local structural projects are built as a possible solution to reduce flood damages. No action means forfeiting potential benefits such as construction related jobs, reduced fear from flooding and the long-run security of decreased flood damages.

10.00 SUMMARY

Based on review of relevant facts pertaining to the public need and environmental considerations, the conclusion reached is that the rehabilitation of the local protection project is in the best public interest. The following points were considered pertinent in evaluation of the project:

(1) The environmental impacts of the project are considered to be very minor. As stated, water pollution has eliminated any species which may have inhabited the river. Therefore, any repair work done will not displace fish or any other aquatic animal species.

(2) Social well being must be considered. It would be disastrous to allow the present conditions to remain as this would endanger the surrounding areas to severe flood damage.

(3) Any flood damage would have a harsh effect on the economy of the city. In addition to the harm to private property which would cause economic hardships, a flood would damage the mainstay of Fitchburg's economy, namely the industries, with the possible result of temporary or even permanent shutdown of plants.

The proposed maintenance project has been found to be the only practicable course of action. Environmental effects have been considered and found to be minimal and total public interest has been considered. The conclusion is that, with all the considerations and alternatives examined, the repair project should proceed.

It is opined that an Environmental Assessment in lieu of an Environmental Impact Statement (EIS) is applicable and sufficient for assessing and evaluating the impacts caused by the project for the following reasons:

a. The work involves the rehabilitation of a previously authorized project and only includes renovations, reconstruction, and some additional similar types of protection works.

b. The stream channel alignment or width is not being changed.

c. New real estate takings or relocations of building or inhabitants are not required. The only real estate activities required are for the purposes of obtaining temporary easements for construction operations where applicable.

d. Due to the previous low water quality rating of the river the temporary impact on fish and plant life in the channels from construction activities is considered minimal (Note: From all indications it is anticipated that the river water quality will greatly improve in the future with the recent completion of two wastewater treatment plants in Fitchburg).

e. Construction of the project will not have any ill effects of social, economic, or public health aspects.

f. The rehabilitation work will enhance the project area from a visual and aesthetic viewpoint.

g. The rehabilitation project does not present any new and/or controversial issues or items of work.

h. The project is considered a minor action and that an Environmental Impact Statement is not reassured.

11.00 COORDINATION WITH OTHER AGENCIES

Coordination has been maintained throughout the course of the planning of this work with Federal, State and local agencies which have responsibilities or interests in the project.

12.00 CONCLUSIONS

Upon evaluating the information presented in this Environmental Assessment Report, it is my belief that construction of the proposed Channel Rehabilitation for local flood protection in the North Nashua River in Fitchburg, Massachusetts as indicated is in the best public interest.

The new work will restore the channel to its 1937 design capacity of 9,000 cubic feet per second of streamflow which will reduce flood damages and various environmental and social-economic impacts. The rehabilitation effort is a restoration of previously authorized and constructed facilities for flood protection purposes. The project may cause minimal temporary inconveniences during the work period only. It is determined that adverse short-term environmental impacts will be minimal and there will be no long-term adverse environmental impacts caused by the project.

In my evaluation, this assessment has been prepared in accordance with the National Environmental Policy Act of 1969 and will be coordinated with appropriate regulatory agencies. From all indications and the type of rehabilitation and restoration work involved, the local protection project is considered a minor action and can be accomplished with subsequent minimization of environmental impacts. The assessment therefore precludes the need for preparation of a formal Environmental Impact Statement.

_____ (Date)

JOHN P. CHANDLER
Colonel, Corps of Engineers
Division Engineer

ATTACHMENT NO. 1

FITCHBURG LOCAL PROTECTION PROJECT
NORTH NASHUA RIVER

PRELIMINARY ABRIDGED SCOPE OF WORK

The preliminary abridged Scope of Work description is developed starting at the upstream limits of the work in the vicinity of the now-removed Cowee's Mill Dam, and proceeding downstream to the Leominster town line below the Fitchburg airport. Bank identification is made looking downstream.

Scope of Work:

The following restorations are proposed:

a. Starting about 700 feet above Oak Hill Street bridge, re-stabilize right bank for about 200 feet and remove random boulders in same region along right bank.

b. Loose stone wall on left bank located about 300 feet upstream of Oak Hill Road bridge to be replaced with similar wall for length of approximately 60 feet. Wash-out of earth adjacent to Routes 12 and 31 to be filled with earth to match existing wall grade surrounding. Estimated fill 100 cubic yards to be placed against new section. Remove portions of breached wall lying in river.

c. At Daniels Street bridge re-grout cut stone wall upstream on right bank for a distance of about 100 feet.

d. Remove a few broken stone boulders immediately downstream of the bridge at left side. Restabilize right downstream bank immediately adjacent to the bridge abutment. Also, install approximately 12 feet of 18" RCP for extending storm sewer at bridge.

e. Repair channel bottom by grouting cut stones for an area of approximately 30 square yards between Kimball Street Bridge and the Boston and Maine Railroad bridge.

f. At River Street Bridge, Route 31, in the vicinity of West Street, remove from both banks dumped granite riprap covering about 125 feet each side. Remove old deteriorated concrete cribbing beneath the dumped granite (Crib Sites 1 and 2). Replace with poured concrete retaining walls and backfill to match surrounding grade. Construct concrete ramp on the right bank.

g. At Sheldon Street Bridge, repair right downstream concrete wall next to bridge.

h. East of Nockege Street immediately downstream of the foot bridge, remove remains of breeched cut stone dam, approximately 80 pieces in 500 - 1000 pound sizes.

i. At River Street Bridge at West Street, Route 31, remove approximately 30 pieces large stone immediately downstream of the bridge. Do not disturb existing 12-inch crossing main in streambed.

j. At Circle Street Bridge, on the left bank downstream, remove dumped granite riprap and deteriorated concrete cribbing. Remove about 200 cubic yards of landslide fill in the streambed. Replace deteriorated cribbing (Crib Site No. 3) with concrete wall or uniform emplaced stone.

k. Along the right bank replace footing blocks in granite wall and re-grout.

l. Downstream of Rollstone Street Bridges, repair eroded grouted riprap on the left bank, about 150 feet in length.

m. About 500 feet upstream of Putnam Street on the right bank, repair existing concrete cribbing (Crib No. 4) by addition of concrete cap and refacing of several eroded stretcher members in a total length of about 150 feet.

n. Construct 325 feet of concrete capping on top of existing wall.

o. At Laurel Street along the right bank above the streambed and adjacent to railroad siding, remove about 250 feet of deteriorated concrete cribbing (Crib Site Nos. 5 and 6) and replace with concrete wall, three sections.

p. At Water Street Bridge, Route 12, vicinity of Walnut Street, upstream of Water Street on the left bank, restore approximately 300 feet of stone wall, removing temporary sand dike, plus material along base of wall in the streambed. Paint 300 feet of existing chainlink fence on top of wall and paint concrete wall.

q. Prior to completion of Item p above, remove existing concrete cribbing, (Crib Site No. 7), 250 feet, along right bank upstream of Water Street Bridge. Replace with concrete wall. Temporary access must be constructed in streambed to accomplish. (Also, consider concrete veneer as an alternate to removal of existing work.)

r. Repairs openings in steel sheeting which protects existing private owned natural gas tank.

s. At the Power Station Dam, remove excess broken stone boulders downstream of the service dam. (Approximately 50 pieces 500 - 1000 pound range.)

t. Immediately upstream of the Harvard Street overpass, remove two mid-stream abutments from prior removed footbridge. Abutment in left bank to be retained but upper two courses of granite block to be re-grouted for safety.

w. Remove the remains of the deteriorated syphon dam below Bemis Road, regrade the area and place riprap protection on the adjacent riverbank area and restore the outlet of the canal into the river.

x. At Bemis Road Dam, remove excess broken stone in stream immediately left downstream. Repair washed out grouted riprap on left bank downstream of the dam.

Misc. Items: Remove various shoal areas debris and selected rocks in the streambed within the project area.

APPENDIX III

SOCIAL AND ECONOMICS EFFECTS ASSESSMENT

DRAFT REPORT
SOCIAL AND ECONOMIC EFFECTS ASSESSMENT
FOR
NORTH NASHUA CHANNEL RESTORATION PROJECT
FITCHBURG, MASSACHUSETTS

APPENDIX III

APPENDIX III
SOCIAL AND ECONOMICS EFFECTS ASSESSMENT

TABLE OF CONTENTS

Introduction

It was the North Nashua River which drew settlers, and later industry, to Fitchburg area to establish a city in the floodplain. Consequently, the highly developed areas of the city have been vulnerable to damage from flooding. After the flood of record in 1936, the Army Corps of Engineers, under the direction of the Works Progress Administration (W.P.A.), constructed the North Nashua River Channel Improvements to control overbank flooding in the city's highly developed riverside area.

Since the channel's construction only emergency maintenance and repair work has been done. The structures have deteriorated to such a degree, that at many points along the four mile strech of the project, they are unable to safely fulfill their design function.

The purpose of the present study is to determine the feasibility of repairing and restoring the channel and consequently improving its usefulness and the appearance of the river where it flows through the city.

Profile of Study Area

Geography

The City of Fitchburg is located in the north central section of Massachusetts in Worcester County. It is 25 miles from Worcester and 46 miles from Boston, bordered by Westminister, Ashby, Lunenburg and Leominister. It is the principal city of the Fitchburg-Leominster Standard Metropolitan Statistical Area, (SMSA). It is at an elevation of 485 feet above sea level with a land area of 27.5 square miles.

Topography

The city is situated along the north branch of the Nashua River. The steeply sloped North Nashua River Valley cuts through the center of Fitchburg. The remainder of the city contains a series of hills and ridges. Elevations within the city range from 340 to 1,220 feet above mean sea level.

Climate

Fitchburg experiences a normal temperature of 25.9° F in January and 72.3 F in July with a normal annual rainfall of 45.5 inches. Major floods are caused by swift runoff from heavy or prolonged rainfall or from snow melting off the steep rocky hills surrounding the valley. The situation of the business district makes it particularly vulnerable at these times.

Land Use

Fitchburg's primary development occurred before the wide-spread use of the automobile and is concentrated within walking distance of the river. Much of the hilly land beyond the North Nashua River Valley has never been developed.

The major transportation routes are also concentrated near the river. These include state highways and railroad tracks. Most of the roads are

Table I
Fitchburg Land Use

	No. of Acres	Percent of land in active use	Percent of all land
Land in Active Use			
High Density Residential Use (more than 1 dwelling per acre)	3,146	58.7	
Low Density Residential Use	930	17.4	
Industrial and Commercial Use	452	8.4	
Public Use (structures and immediate grounds only)	175	3.3	
Agrucultrual Use	603	11.3	
Other Uses	50	0.9	
All Land In Active Use	5,356	100.0	29.8
Land not in Active Use	12,644		70.2
All Land	18,000		100.0

Source: Draft Report Prepared by the Fitchburg Planning Office

narrow with sharp turns and steep grades. Roads and railroad tracks cross the river at many locations.

Of the city's approximately 18,000 acres 5,356, or 29.8%, are in active use. Of land in active use over half is high density residential area, 8.4% is industrial and commercial development, 11.3% of the land is in agricultural use and 17.4% is low density residential areas. Table 1 indicates the breakdown of land use by major catagories.

During the first decade of the nineteenth century, attracted by the concurrance of a labor market and power source in the river settlement, Gen. Leonard Burbank established a paper mill and dam near a fall in the North Nashua River. Other mills - cotton, paper and lumber - followed. Later, as transportation developed and population grew, other industries were attracted to the area.

Today, manufacturing is the most important industry in the city, employing 36.3% of the workforce. The paper and allied products industries are still very important, accounting for almost 25% of the manufacturing total, second only to metal fabrication. Tables II and III provide breakdowns of economic activity in Fitchburg.

Fitchburg has followed the general development pattern of much of New England since the Industrial Revolution. Formerly a most important manufacturing region, its standing has considerably declined. One reason for this has been the de-emphasis of the use of rivers for power and processing. Other factors in the city's manufacturing decline have been the relatively favorble labor

Table II
Employment by Industry
in Fitchburg, 1975

	Number of People Employed	Percentage of Employed
Manufacturing	7,156	36.3
Wholesale/Retail Trade	3,988	20.3
Service & Mining	3,097	15.7
Government	2,182	11.1
Other non-manufacturing	3,271	16.6
TOTAL	19,694	100.0

Source: Montachusett Regional Planning Commission

Table III
Manfacturing Employment by Industry
in Fitchburg, 1975

	Number of People Employed	Percent Employed in Manfucturing	Percentage of Total Employed
Durable Manufacturing			
Fabricated Metals	1,602	22.4	
Non-Electrical Machinery	1,353	18.9	
Instrumentation	219	3.0	
Other Durable Manufacturing	498	7.0	
Total Durable Manufacturing	3,672	51.3	
Non- Durable Manufacturing			
Textiles	220	3.1	
Apparel	384	5.4	
Paper	1,455	20.3	
Rubber	662	9.2	
Leather	357	5.0	
Other Non-Durable	406	5.7	
Total Non- Durable Manufacturing	3,484	48.7	
Total Manufacturing	7,156	100.0	36.3

Source: Montachusett Regional Planning Commission

market of other regions of the country and the tendency of people to move out of the cities. A summary of projections of economic activities is presented in Table IV.

Population

According to the 1960 U.S. Census, Fitchburg had a population of 43,021. The 1970 Census showed a population of 43,343, an increase of 322 or 0.7%, in that decade. As there were 3,831 more births than deaths in the City in that decade, it appears that 3,509 more people moved out of than into the city. This is probably a reflection of both the decline in the job market relative to the rest of the country at the time, and the continuing trend of movement to the suburbs. It follows the trend of comparable cities in the region such as Worcester and Lowell. These trends are expected to continue to be major influences on population in Fitchburg and the region Table V indicates population projections for Fitchburg through the year 2000.

Table IV
PROJECTIONS FOR MAJOR ECONOMIC SECTORS OF FITCHBURG, MA.

Table IV A
Number of People Employed

	1975	1980	1985	1990
Manufacturing				
Durable Manufacturing				
Fabricated Metals	1,602	1,561	1,523	1,495
Non-Electrical Machinery	1,353	966	837	651
Other	717	668	757	977
Total Durable Manufacturing	3,672	3,195	3,126	3,123
Non-Durable Manufacturing				
Paper	1,455	1,983	3,181	2,248
Other	2,029	1,856	1,775	1,541
Total Non-Durable Manufacturing	3,484	3,839	3,956	3,789
Total Manufacturing	7,156	7,034	7,091	6,912
Wholesale/Retail Trade	3,988	4,134	4,034	3,928
Services - Mining	3,097	3,801	4,408	5,098
Government	2,182	2,234	2,329	2,392
Other Non-Manufacturing	3,271	2,278	3,322	3,111
TOTAL	19,694	20,581	21,184	21,441

Source: Montachusett Regional Planning Commission

Table IV B
Employment in Economic Sectors as a Percent of Total Employment in Fitchburg

	1975	1980	1985	1990
Manfucturing				
Durable Manufacturing				
Fabircated Metals	8.1	7.6	7.2	7.0
Non-Electrical Macherinery	6.9	4.7	4.0	3.0
Other	3.6	3.2	3.6	4.5
All Durable Manufacturing	18.6	15.5	14.8	14.5
Non-Durable Manufacturing				
Paper	7.4	9.6	10.3	10.5
Other	10.3	9.1	8.4	7.2
All Non-Durable Manufacturing	17.7	18.7	18.7	17.7
All Manufacturing	36.3	34.2	33.5	32.2
Wholesale/Retail Trade	20.3	20.1	19.0	18.3
Services - Mining	15.7	18.5	20.8	23.8
Government	11.1	10.8	11.0	11.2
Other Non-Manufacturing	16.6	16.4	15.7	14.5
TOTAL	100.0	100.0	100.0	100.0

Table V
Population Projections for
Fitchburg, MA

	1975	1980	1985	1990	1995	2000
High	44,000	44,300	44,610	44,900	45,180	45,430
Average	43,540	43,725	43,895	44,100	44,285	44,445
Low	43,080	43,150	43,180	43,300	43,390	43,460

Source: Draft Report prepared by the Fitchburg Planning Office

Without Project Future Condition

Without the project, the channel's capacity for handling flood waters will decline. The channel will no longer be able to fulfuill its design function of handling 9,000 c.f.s. and the deterioration of its structures will continue. The debris resulting from such deterioration will tend to impede the flow of water by catching any other debris which may be in the River. This would further impede the flow of water through the channel. Thus, over time, damages related to flooding will tend to increase.

The water in the river had become extremely polluted by industrial and municipal wastes, but recently, through the efforts of the various communities using the river, this trend has been reversed. One of the major accomplishments has been the development and use of two new waste water treatment plants in Fitchburg. Because of these improvements and the large expense involved there has been increased interest in the river's future uses. This interest has centered on developing the river as a center city recreation area. The resultant plans call for a walkway and bike path through a greenbelt connecting several community recreation areas. The 'greenbelt project' is part of the City's Comprehensive Plan to provide needed recreation in the City's core area and to enhance the Central Business District. Without these improvements there is expected to be a continuing decline in the commercial area and a strong tendency for those residents who are able to do so to move out of the city.

Formulation of Alternatives

No Action

The no action policy reflects the without project condition. The rate of deterioration of the channel will continue. Losses due to flood damages will continue to increase. Due to current EPA regulations and public interest the amount of debris in the river due to industrial waste will continue to decrease. The quality of water will continue to improve because of the new water treatment plants. The implementation of the city's plan for the re-development of the area would be hindered without the project.

Recommended Plan

The proposed rehabilitation of the North Nashua Local Protection Project encompasses repair and restoration along approximately four miles of the channel in Fitchburg. This portion of the channel extends from about 700 feet upstream of Oak Hill Street Bridge to Siphon Dam at Falulah Road. The actual work will take place at specific points along the channel where deterioration is evident. As some of these points the project will provide for the removal of debris resulting from various sources such as; cut stone blocks, random boulders and the remains of old bridges and dams. Other work would include the repair and replacement of stone walls, grouted rip rap and dams. At one location this will involve the construction of temporary ramp access into the stream bed.

Discussion of Social & Economic Impacts

The Water Resource Council's Principles and Standards require that proposed plans continually be evaluated with regard to objectives of national economic development, environmental quality, regional development, and social well-being. Interacting social, economic, and environmental factors may bring about both adverse and beneficial impacts which will have short or long term effects in the study area. This section discusses the social and economic impacts of the proposed project.

Since this would be a restoration project, the impact on the area would be moderate. It would be primarily a comparison between the continuing deterioration of the channel structures without the project and the restoration and maintenance of the original project. Most of the direct project benefits accrued would be to the capacity of the restored channel to handle flooding. By restoring and maintaining the channel at a 9,000 c.f.s. capacity the total average annual benefits would be $415,000 due to decreased damages attributable to flooding. During the construction period there would be temporary adverse effects due to the use of large trucks and machinery in an urban area. There would be an increased demand on already heavily travelled city streets, many of which tend to be highly graded and narrow, with many corners. Most, if not all, of the track traffic would be limited to non-residential streets, reducing the adverse health and safety effects on the inhabitants of the city. There might be some increase in air pollution levels and the river may get muddier due to the activity of heavy machinery and disturbance of the river bottom.

As for long range adverse effects there are none. There would be no displacement of people or farms no interference with or demands on public

services and facilities.

On the plus side, the project would provide a site for some planned recreational development. It should improve the esthetic quality of the area and consequently benefit the social well-being of the city. Property values may rise, increasing tax revenues, making the city more attractive to residents and potential residents and hopefully, attract more business to the area. By improving recreational opportunities in the central city, benefits from the project accure to the moderate income residents of Fitchburg who find it particulary difficult to travel to suburban or rural recreation area. This includes older people, children, and people who live and work in the city. This extra benefit to city dwellers may also help reduce the tendency for the middle and higher income groups to relocate out of the city. This movement to the suburbs tends to; a) reduce the tax base and b) place demands on public services to supply fewer scattered residents at a higher cost. Thus, its reduction would tend to increase the disposable income of the city and its residents.

In summary, the present plan would produce for 1-1/2 years, at most, adverse effects of heavy construction, i.e. noise, pollution and traffic problems, and would provide for approximately fifty years, benefits in form of reduced flood losses, improved appearance, and the other social and economic benefits.

Display of Social and Economic Impacts of Proposed Plan for Rehabilitation of North Nashua River Channel

	Social		Economic	
Project Phase	Short Term	Long Term	Short Term	Long Term
Construction Costs and Adverse Impacts	Traffic Problems Increased Noise Possible Increased Pollution	NONE	Construction Costs @ $1.23 million Paid by Federal Government	Easement and Rights of Way Provided by the City of Fitchburg
Benefits	NONE	NONE	Increased Employment, Wages	NONE
Post-Construction Costs and Adverse Impacts	NONE	NONE	NONE	Maintenance costs of about $5,400 Annually
Benefits	NONE	Improve Esthetic Qualtiy of Area, Increase Attractiveness of City, Support City's Long Range Plan	NONE	Total average annual flood prevention and area redevelopment benefits of $428,000 (based on 3-1/4%)